A STUDY OF METHODS USED IN

MEASUREMENT AND ANALYSIS OF SEDIMENT LOADS IN STREAMS

SUBCOMMITTEE ON SEDIMENTATION
INTER-AGENCY COMMITTEE ON WATER RESOURCES

REPORT N

Progress Report

INTERMITTENT PUMPING-TYPE SAMPLER

FEBRUARY 1960

A Study of Methods Used in

MEASUREMENT AND ANALYSIS OF SEDIMENT LOADS IN STREAMS

A Cooperative Project
Sponsored by the
Subcommittee on Sedimentation
Inter-Agency Committee on Water Resources
(Formerly Federal Inter-Agency River Basin Committee)

Participating Agencies

Corps of Engineers	**	Geological Survey
Soil Conservation Service	**	Bureau of Reclamation
Agricultural Research Service	**	Coast and Geodetic Survey
Tennessee Valley Authority	**	Federal Power Commission
Bureau of Public Roads	**	Forest Service

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TABLE OF CONTENTS

Section	Page
I. INTRODUCTION	
1. Purpose of this development	7
2. Personnel and acknowledgments	7
II. LOCATION AND STREAM FLOW CHARACTERISTICS	
3. Location	8
4. North Loup River	8
5. Stream flow pattern	8
6. Suspended Sediment	11
III. PUMPING SYSTEM	
7. Shelter	13
8. Basic operation	14
9. Cycle of operation	14
10. Pumps	17
11. Splitter	18
12. Sedimentation tank	18
IV. INTAKE	
13. Structure	21
14. Intake	21
15. Fish trap	21
V. OPERATION OF INTAKE AND PUMPING SYSTEM	
16. Period of operation	25
17. The operational record	25
18. Evaluation of operational record	27

Section Page

VI. SAMPLING EFFICIENCY

19. Procedure 28
20. Splitter tests 28
21. St. Paul intake tests 29
22. Dunning intake tests 29
23. Relation of river concentration to concentration at intake. . . . 32
24. Flushing water tests 34

VII. RECORDING SYSTEM

25. Operation 36
26. Weighing pan 36
27. Baffles 36
28. Crane scale 36
29. Recorder 40
30. Spring-transformer scale 41

VIII. OPERATION OF RECORDING SYSTEM

31. Determination of sediment concentration 46
32. Operation of the crane scale and recorder 47
33. Operation of the spring-transformer scale 49

IX. FUTURE PROGRAMMING OF INTERMITTENT PUMPING SAMPLER

34. Further work on present installation 51
35. Future installations 51

X. CONCLUSIONS

36. Conclusions 52

XI. APPENDIX

37. Description of gaging station 53
38. Description of sediment station 56
39. Results of St. Paul intake tests 56

LIST OF ILLUSTRATIONS

Figure		Page
1.	Location of the intermittent pumping sampler	9
2.	Reach of the North Loup River near St. Paul, Nebraska	10
3.	Intermittent pumping sampler shelter	13
4.	Schematic diagram of the intermittent pumping sampler	15
5.	Control system for the intermittent pumping sampler	16
6.	Cycle indicator	17
7.	Splitter assembly	19
8.	Sedimentation tank and pit details	20
9.	Intake structure	22
10.	Types of intakes tested	23
11.	Fish trap	24
12.	Results of standard intake tests	30
13.	Results of elbow intake tests	31
14.	Results of nipple intake tests	31
15.	Weighing pan	37
16.	Crane scale	38
17.	Recorder and crane scale circuit diagram	39
18.	Recorder	40
19.	Spring-transformer scale	42
20.	Stepping system for spring-transformer scale	43
21.	Spring-transformer scale circuit diagram	44
22.	Recorder chart	48

LIST OF TABLES

Table		Page
1.	Summary of water discharges North Loup River for periods of sampler operation	12
2.	Operational record of the intermittent pumping sampler	26
3.	Lag in sample concentration at splitter	28
4.	Intake tests at Dunning, Nebraska	33
5.	Cross-section samples North Loup River near St. Paul, Nebraska	34
6.	Flushing water tests	35
7.	Sampling efficiency	49
8.	Daily water discharges North Loup River for periods of sampler operation	54
9.	Sediment discharge measurements North Loup River for periods of sampler operation	57
10.	Results of standard intake tests	59
11.	Results of elbow intake tests	61
12.	Results of nipple intake tests	62

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FEDERAL INTER-AGENCY SEDIMENTATION PROJECT

ST. ANTHONY FALLS HYDRAULIC LABORATORY

HENNEPIN ISLAND & THIRD AVE., S. E.

MINNEAPOLIS 14, MINNESOTA

Progress Report

INTERMITTENT PUMPING-TYPE SAMPLER

I. INTRODUCTION

I. Purpose of this development--Work on the intermittent pumping-type sampler is part of an investigation aimed at development of new devices to automatically measure suspended-sediment loads in streams. Although the development is based on a consideration of all factors involved in the discharge of suspended sediment, the problem has been simplified in the primary stages by concentrating on the determination of the suspended-sediment concentrations at one point in the cross-section of a stream.

The pumping sampler investigation is in two parts: (1) development of an intake and pumping system that will collect a representative sample from the stream, and (2) development of a recording system that will record sediment concentration accurately.

2. Personnel and acknowledgments--The Federal Inter-Agency Sedimentation Project is located at the St. Anthony Falls Hydraulic Laboratory, University of Minnesota, under the immediate supervision of an Inter-Agency Technical Committee. The general project is sponsored by the Subcommittee on Sedimentation of the Inter-Agency Committee on Water Resources. Funds are contributed by the Geological Survey, Corps of Engineers, Soil Conservation Service, Bureau of Reclamation, Agricultural Research Service, and Tennessee Valley Authority.

The report was prepared by H. H. Stevens Jr. who built and operated the field installation and assisted in the design of the unit. B. C. Colby, project supervisor, developed the general design; supervised the operation; and reviewed the report.

Mr. D. M. Culbertson, District Engineer, Quality Water Branch, U. S. Geological Survey, Lincoln, Nebraska, furnished personnel to help in the field construction and to collect and analyze suspended-sediment samples. Mr. A. F. Pendleton, Engineer-in-charge, Surface Water Branch, U. S. Geological Survey, Grand Island, Nebraska, furnished personnel to help in the maintenance of the field installation.

Pumping samplers have been used before. One of the most elaborate installations was reported by G. Braudeau in La Houille Blanche, Numero Speciala, Mai 1951.

II. LOCATION AND STREAM FLOW CHARACTERISTICS

3. Location--The intermittent pumping sampler is installed on the North Loup River 3 miles north of St. Paul, Nebraska. (See Fig. 1 & 2.) The sampler installation is on the south bank of the river 230 feet downstream from the bridge on U. S. Highway 281.

The North Loup River was chosen for this field study because it has a continuous water and sediment discharge. The St. Paul site was chosen because of the stream-gaging and sediment-sampling station and the availability of power. The river banks at this site are sufficiently high to prevent submergance of equipment during flood flows. A bend in the river upstream from the highway bridge tends to concentrate the flow near the south bank, a condition which simplified the design of the intake structure.

4. North Loup River--The North Loup River flows in a general southeasterly direction joining the Middle Loup River 4 miles below St. Paul, Nebraska, to form the Loup River. The total length of the North Loup River is about 190 miles. The main tributary is the Calamus River which joins the North Loup River near Burwell, 60 miles above St. Paul.

The upper two-thirds of the North Loup Basin is in the sandhills region of north-central Nebraska. The sandhills are blanketed by dune sand of varying depths on moderate slopes, which are stabilized by grass cover. The remainder of the basin is overlain with loess on rolling to steep slopes. This area is used for general farming.

5. Stream flow pattern--The drainage area of the North Loup River upstream from St. Paul is 4,460 square miles, of which only about 1,270 square miles contribute directly to surface runoff. The soil in the sandhill region readily absorbs rainfall and drainage out of the region is from ground water which provides stable stream flow. In contrast, storm runoff from the loess area produces large fluctuations in stream discharge. (See the Appendix, Section 37.)

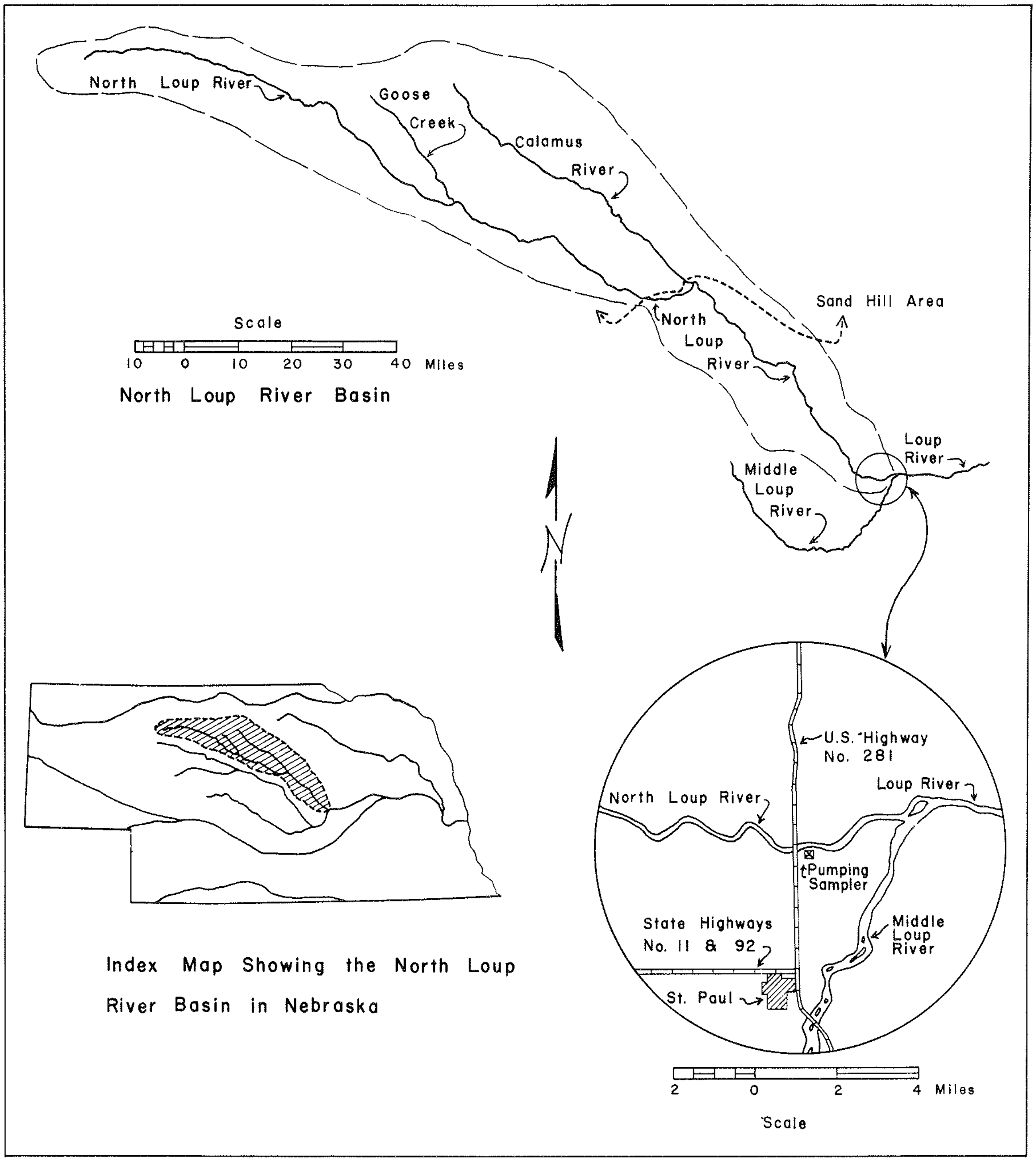


FIG. 1 — LOCATION OF THE INTERMITTENT PUMPING SAMPLER

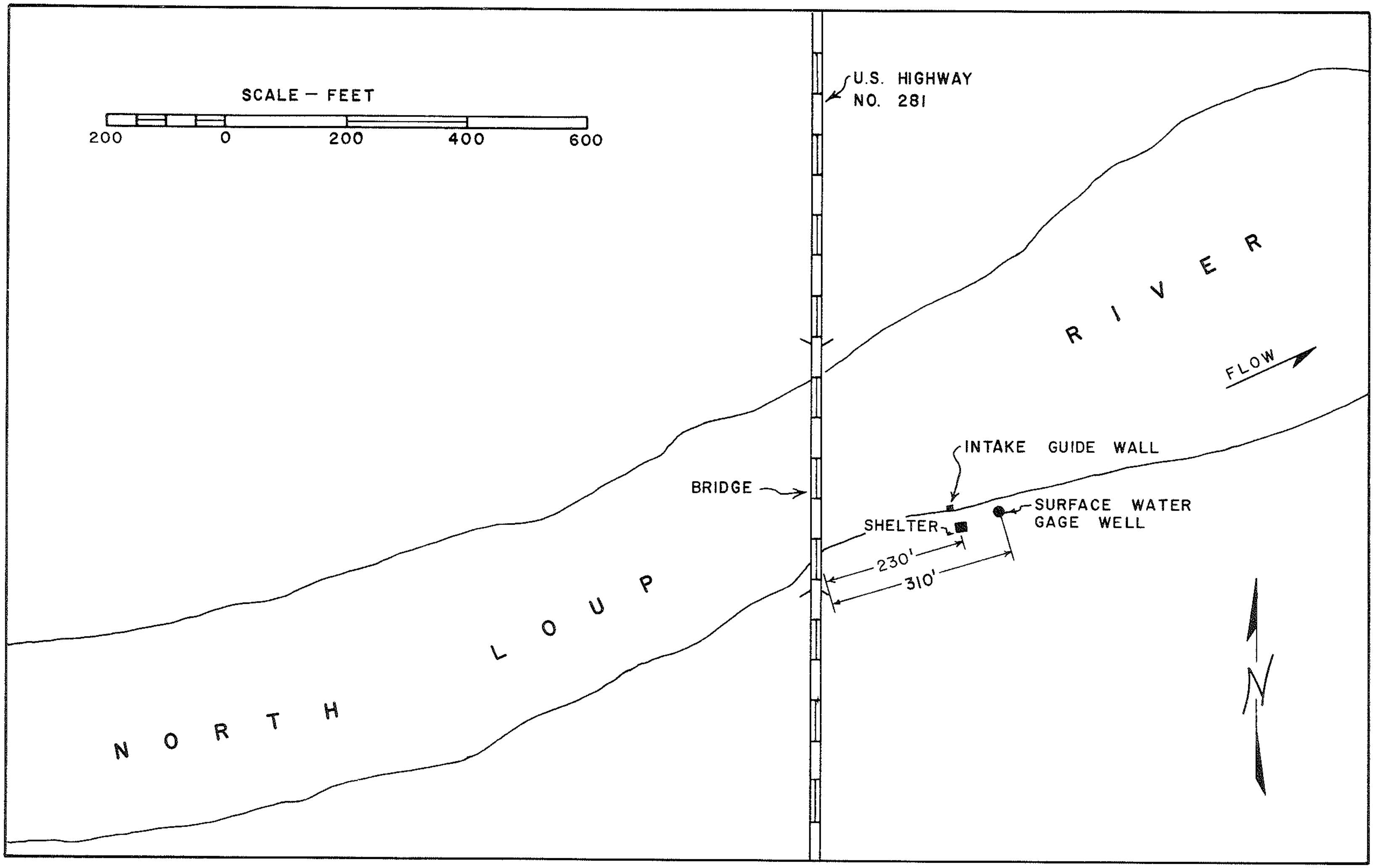


FIG. 2 — REACH OF THE NORTH LOUP RIVER NEAR ST. PAUL, NEBRASKA

The average discharge of the river over 31 years of record (1895-97, 1928-57) was 888 cfs (cubic feet per second). The maximum daily flow during the above period was 90,000 cfs on June 6, 1896, and minimum daily flow was 85 cfs on August 8, 1941. Water discharges during the periods that the intermittent pumping sampler was in operation are summarized in Table 1. The daily discharges are shown in Table 8, in Section 37 of the Appendix. The figures shown are from provisional records and are subject to revision. The mean daily discharge for the 80 day operating period in 1957 was 1,051 cfs, 929 cfs for the 162 day period in 1958, and 764 cfs for the 182 day period in 1959. The maximum daily discharge within the periods of sampler operation was 4,860 cfs on July 24, 1958 and the minimum daily discharge was 303 cfs on August 1, 1959.

6. Suspended sediment--Records of suspended-sediment discharge of the North Loup River near St. Paul, Nebraska, are available from April 11, 1946 to September 30, 1958. Daily measurements were made from April 11, 1946 to June 30, 1953. Periodic measurements were made during the remainder of the period. The maximum daily sediment discharge during the period April 11, 1946 to June 30, 1953 was 463,000 tons on June 22, 1947; and the minimum daily sediment discharge was 20 tons on August 3, 1946, and February 22, 1953. The maximum daily sediment concentration during the same period was 17,200 ppm (parts per million) on April 27, 1951. (See Appendix, Section 38.) The maximum observed concentration was 33,600 ppm at 9:45 a.m., April 27, 1951. The maximum observed concentration during the period July 1, 1953, to September 30, 1958, was 23,000 ppm at 9:30 a.m., July 9, 1958.

During low flows the sandhill area is the main source of water and suspended sediment. Size analyses of suspended-sediment samples collected during periods of low flow show that about 48 percent is finer than 0.062 millimeter and 100 percent is finer than 0.50 millimeter. The median particle size not weighted with water discharge is about 0.069 millimeters. The main source of water during high flows is storm runoff from the loess region in the lower part of the river basin. Size analyses of suspended-sediment samples from periods of high flow, above 2,000 cfs, show that about 88 percent is finer than 0.062 millimeter and 100 percent is finer than 0.50 millimeter. The unweighted median particle size is about 0.009 millimeters.

TABLE 1

SUMMARY OF WATER DISCHARGE NORTH LOUP RIVER
FOR PERIODS OF SAMPLER OPERATION
[in cu ft per sec]

	No. Days	Mean	Maximum	Minimum
1957 (Sept. 2 - Nov. 20)				
September 2 - 30	29	957	2,670	544
October	31	1,095	2,440	836
November 1 - 20	20	1,119	1,350	968
Period	80	1,051	2,670 on 9/14	544 on 9/3-4
1958 (Apr. 30 - Oct. 8)				
April 30	1	1,450	1,450	1,450
May	31	1,016	1,370	790
June	30	913	1,170	696
July	31	1,435	4,860	685
August	31	558	1,030	406
September	30	711	1,280	452
October 1 - 8	8	891	942	836
Period	162	929	4,860 on 7/24	406 on 8/21
1959 (Apr. 28 - Oct. 26)				
April 28 - 30	3	1,087	1,130	1,040
May	31	1,060	1,370	824
June	30	723	1,400	526
July	31	656	1,500	291
August	31	450	588	303
September	30	721	1,070	509
October 1 - 26	26	976	1,090	824
Period	182	764	1,500 on 7/6	291 on 7/31

III. PUMPING SYSTEM

7. Shelter--The equipment shelter (Fig. 3) is an 8 by 10 ft frame building 30 ft from the right bank of the river and 230 ft downstream from the highway bridge. The sedimentation tank and pumping equipment are located in the foundation. The large double door on the stream side of the building is an exit for emptying the weighing pan. A waste way to carry unwanted samples leads back to the stream. A 110-220 volt electric service is supplied by the local R.E.A. company.

Fig. 3A

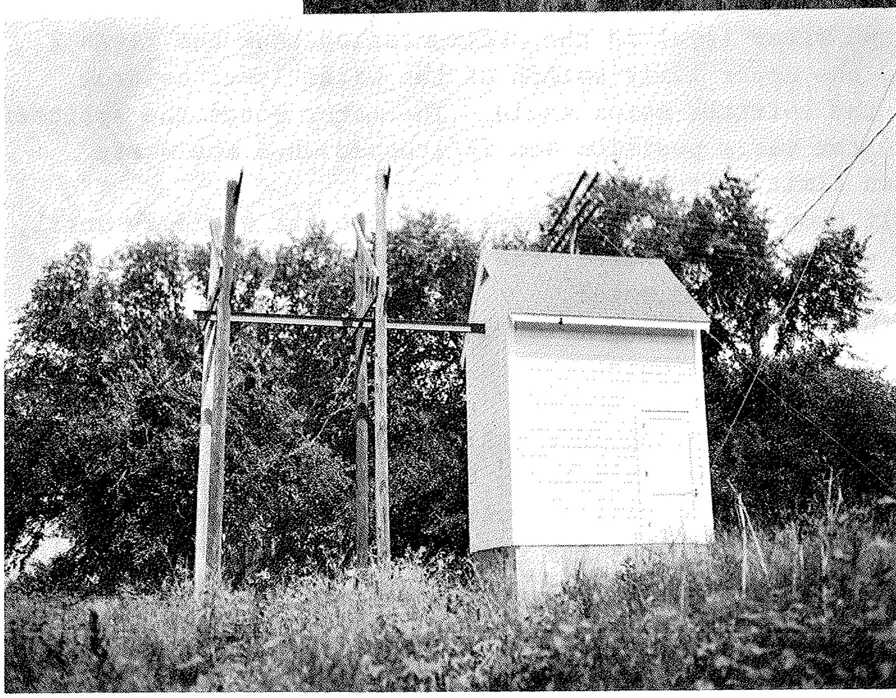


Fig. 3B

Fig. 3 - INTERMITTENT PUMPING SAMPLER SHELTER

8. Basic operation--A schematic diagram of the intermittent pumping sampler is shown in Fig. 4. A 28-gallon sample is pumped into the sedimentation tank every 30 minutes. Preceding each sampling period, 28 gallons of the nearly clear water at the top of the sedimentation tank is pumped back through the intake system to remove any debris or sediment that collected in the intake during the interval between pumping cycles.

9. Cycle of operation--The cycling is controlled by the electrical system (Fig. 5) which operates as follows:

a. The cycle of operation is started when the primary timing motor (1/30 rpm) and cam start the flush pump which pumps the top 2 inches of supernatant liquid out through the intake.
b. When the water level in the sedimentation tank reaches a predetermined level the lower limit switch of the water level control stops the flush pump and starts the silt pump and secondary timing motor (1/4 rpm).
c. During the first 50 seconds that the silt pump operates the splitter is in the waste position to allow the sediment concentration in the pumped flow to become constant.
d. At the end of the waste time a cam on the secondary timing motor starts the splitter motor which moves the supply line to the sampling position. When the sampling position is reached, the splitter control arm opens the sample position limit switch and the motor stops.
e. After the water level in the sedimentation tank has risen 2 inches, the upper limit switch of the water level control starts the splitter motor again. The motor moves the splitter back to the waste position and is stopped when the waste position limit switch opens.
f. The silt pump continues to discharge into the wasteway until, at the end of four minutes, the pump is stopped by a cam on the secondary timing motor.
g. Since the primary timing motor continues to run, the cycle is repeated every 30 minutes.

If the silt pump fails to bring in a full sample because the intake is plugged or the stream is below the intake, the upper water level limit switch will not close, and the splitter motor will not move the splitter back to the waste position. The safety switch on the splitter control will then remain open and the pumps will not operate during the following cycle periods.

Two double-pole single-throw (DPST) switches permit manual operation of the pumping cycle between the regular cycle periods and also allow use of the silt pump to fill the sedimentation tank.

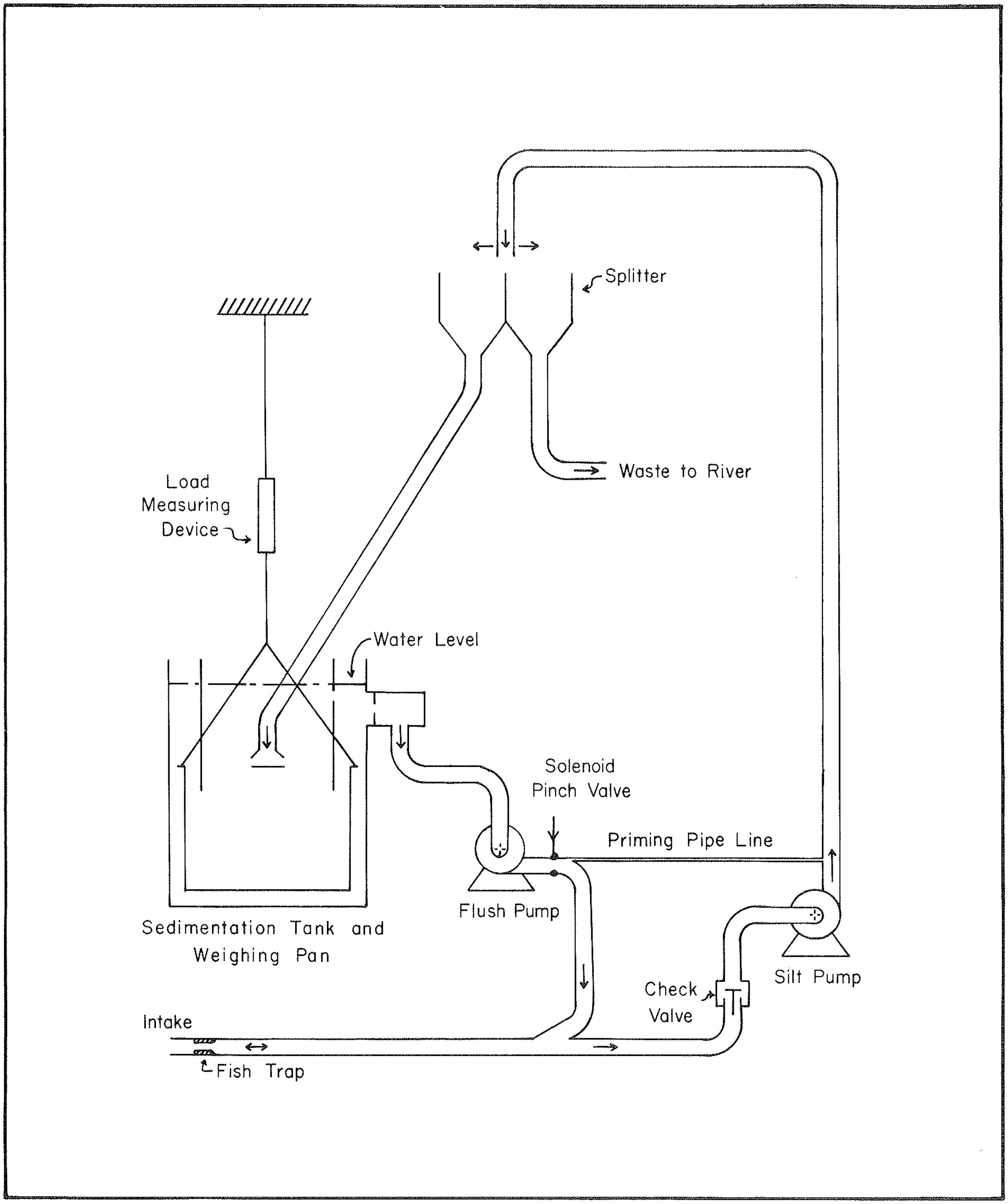


FIG. 4 – SCHEMATIC DIAGRAM OF INTERMITTENT PUMPING SAMPLER

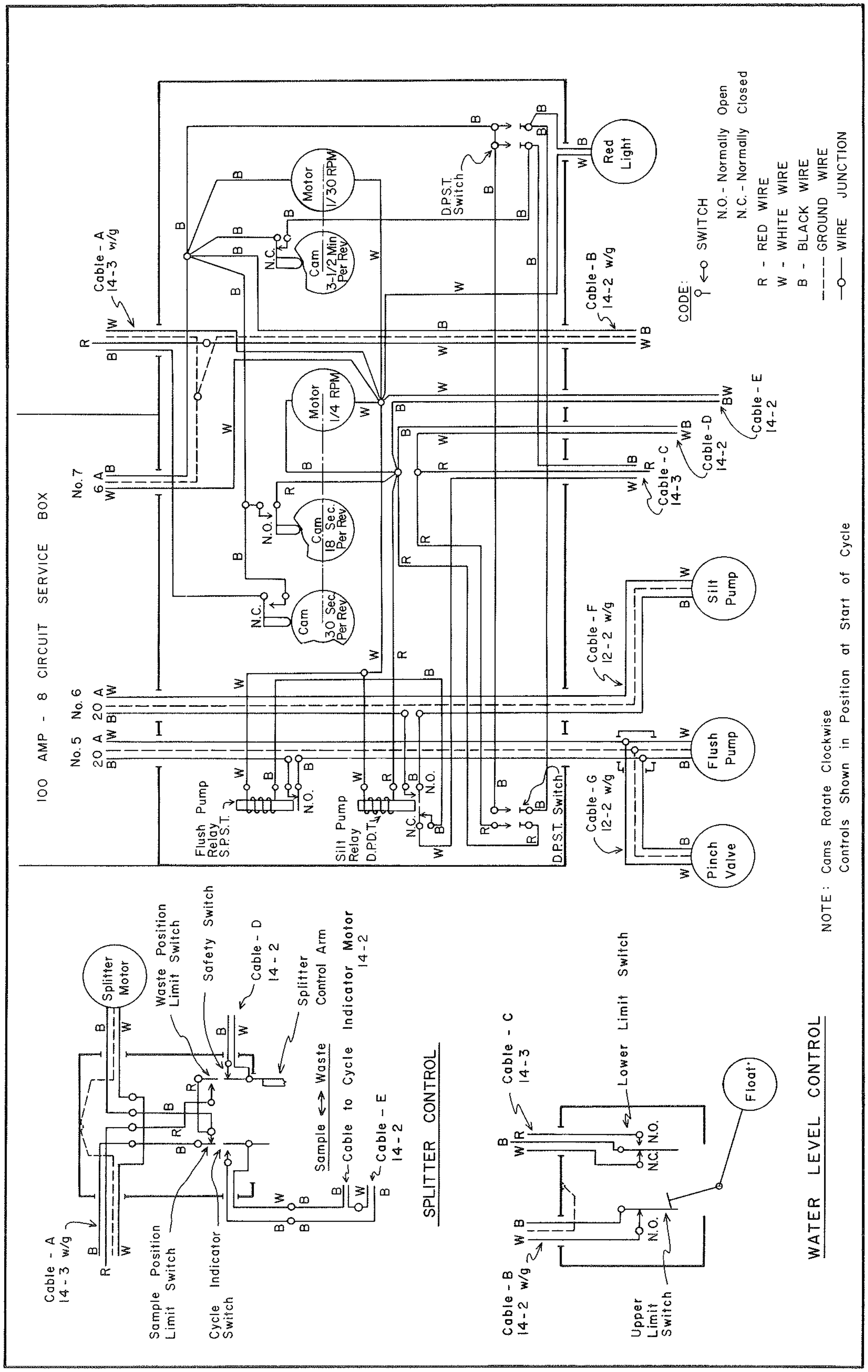


FIG. 5 - CONTROL SYSTEM FOR THE INTERMITTENT PUMPING SAMPLER

Whenever the splitter is in the sampling position, the cycle indicator switch on the splitter control is closed and the cycle indicator motor is activated. This motor operates an auxiliary pen in the load recorder to make a series of short dashes on the right side of the recorder chart. (See Fig. 6.)

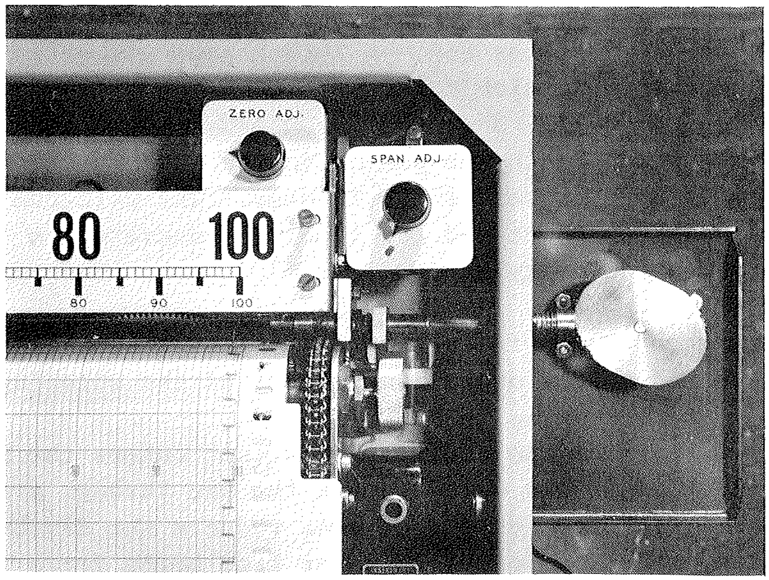


FIG. 6 - CYCLE INDICATOR

10. Pumps--A pump with a flexible rubber impeller and driven by a one-horsepower, 1,750 rpm, electric motor was selected as the most suitable silt pumping unit. The pumps will handle a water-sediment mixture with solids up to 10% by weight. The suction and discharge openings are 1-inch pipe. The discharge is 10 gallons per minute to maintain a velocity of at least 4.5 ft/sec in the intake. The total pumping head is 42 ft (18 ft lift and 24 ft friction head). A check valve helps maintain prime in the silt pump. (See Fig. 4.) Also a small pipe from the flush pump line supplies extra water to restore prime when a twig or other debris prevents complete closing of the check valve between pumping cycles.

The flush pump unit is the same type as the silt pump unit. A smaller flush pump would be adequate but duplicate units simplified construction and replacement of parts. A normally closed solenoid pinch valve is used in the flushing line because the impeller type pump will not seal itself when stopped. The solenoid valve was selected for economy.

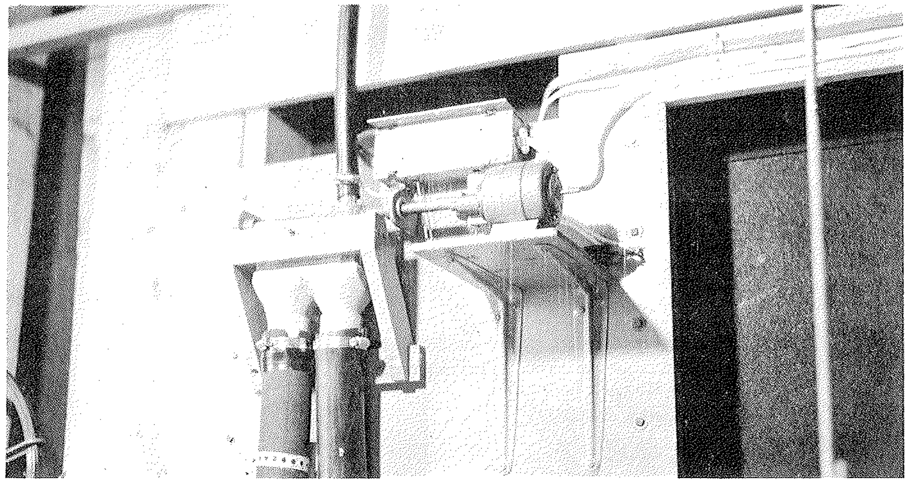
The safety switch on the splitter described in Section 9 keeps the pumps from running when dry. Overheating quickly destroys the pump impellers when the pumps are run dry.

11. Splitter--The splitter assembly is shown in Fig. 7. The river water from the silt pump is discharged into the splitter through a flexible pipe. A 1.7 rpm gear motor moves the splitter supply line between the waste and sampling positions. Two limit switches control the movement of the splitter rod. A 2-inch pipe connects from the splitter to the sedimentation tank.

12. Sedimentation tank--The sedimentation tank is shown in Fig. 8. The tank is 4 ft 8 in. square and 6 ft deep. The wall construction is waterproofed concrete block and the floor is concrete. A floor drain and valve provide for emptying the tank.

The sample from the splitter enters the tank through a diffuser. The diffuser helps reduce the disturbing effect of the entering sample.

The clear water from the sedimentation tank enters the flush pump through an inlet pan. The water enters the pan through a series of ten 1-inch holes. This large discharge area reduces the discharge velocity of the flushing water and prevents water from being drawn from the lower levels of the sedimentation tank.



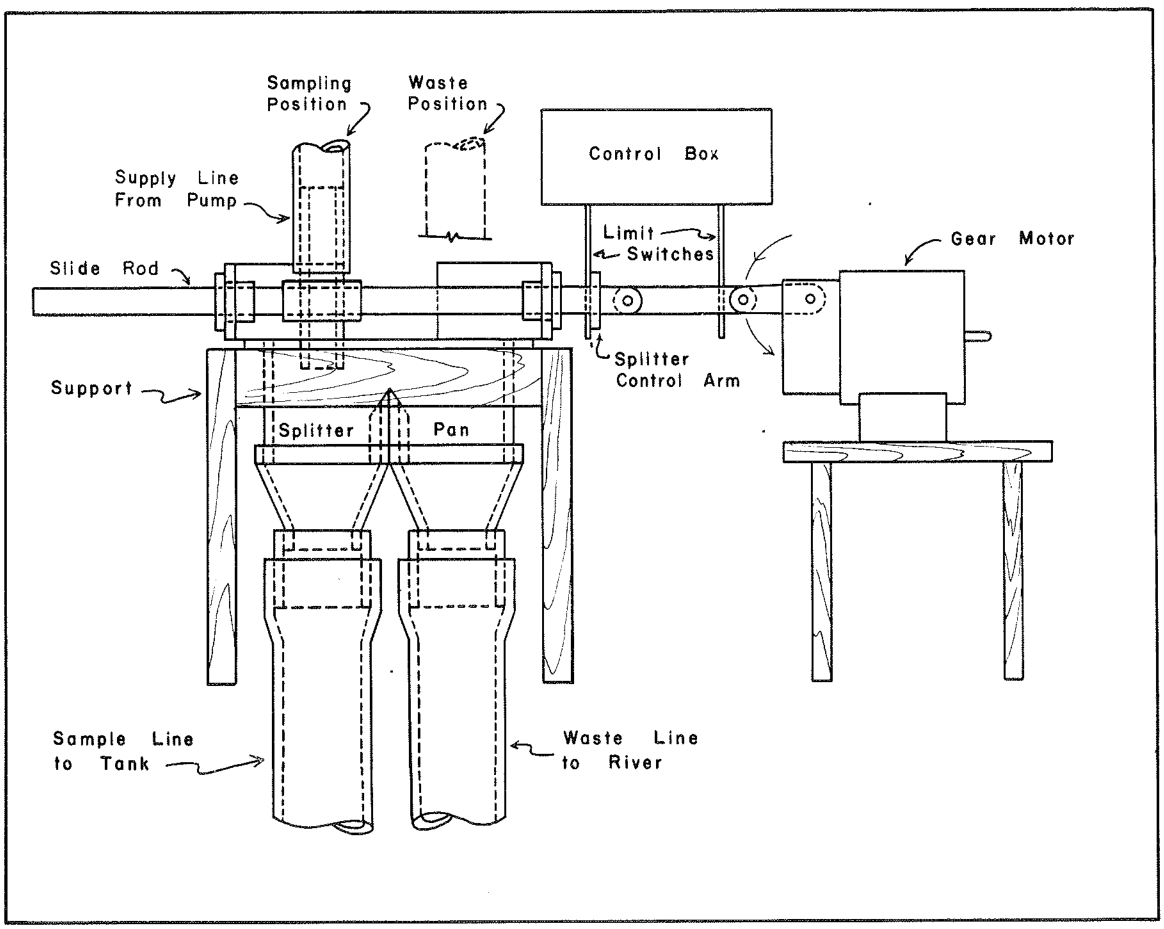


FIG. 7 - SPLITTER ASSEMBLY

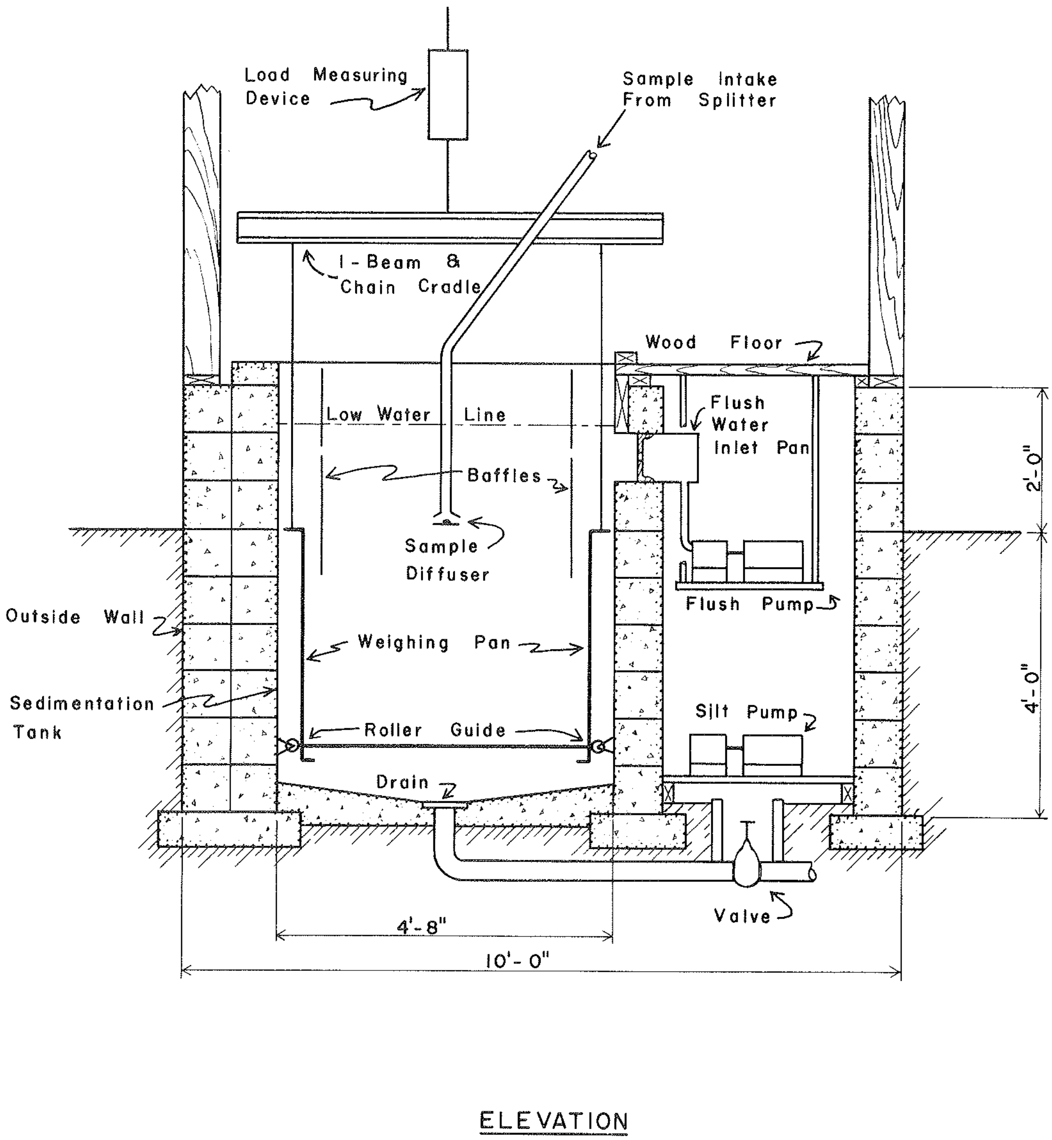


FIG. 8 - SEDIMENTATION TANK AND PIT DETAILS

IV. INTAKE

13. Structure--The intake structure, shown in Fig. 9, consists of a guide wall which is parallel to the stream flow. The guide wall is two 8-ft, 2 x 10 in. planks and one 8-ft, 2 x 6 in. plank mounted on 4 x 4 in. posts. The upstream post is fastened to an old bridge pier and the downstream post is braced to the river bank. The structure has withstood two winter ice flows without damage.

14. Intake--The standard intake consists of a 1-in. pipe coupling welded to a steel plate and mounted flush to the face of the guide wall. Three intakes are mounted on the guide wall to provide easy adjustment of intake elevation. A 1-in. plastic pipe connects the intake to the silt pump. The various types of intakes that have been tested are shown in Fig. 10. The modifications consisted of an elbow intake or one of the three nipple intakes threaded into the outer end of the standard intake coupling.

15. Fish trap--A fish trap, shown in Fig. 11, was inserted in the plastic pipe about 5 ft from the river intake. The rectangular constriction has a slightly smaller cross sectional area than the inside of the plastic pipe.

All except the smallest fish that enter the intake are trapped ahead of the constricted section and flushed back out the intake during the flushing period of the next pumping cycle.

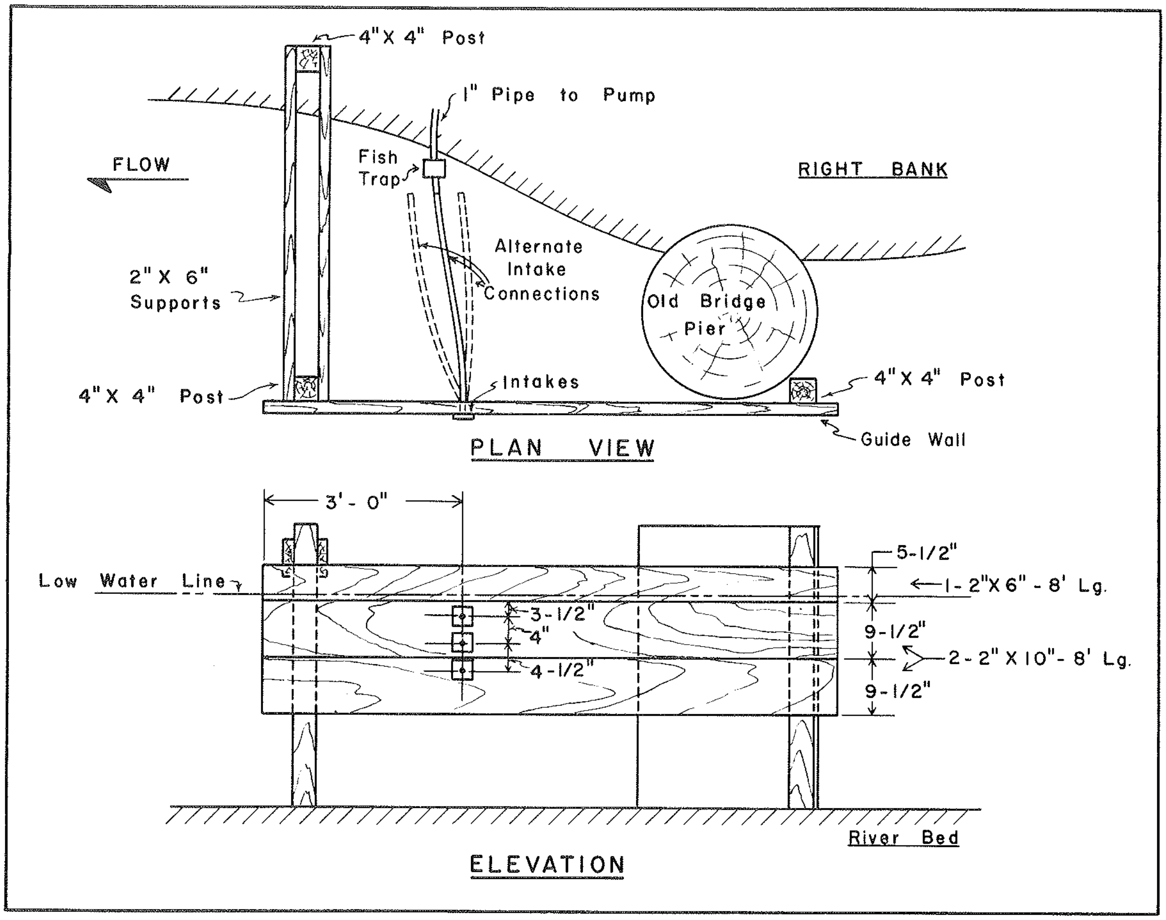


FIG. 9 - INTAKE STRUCTURE

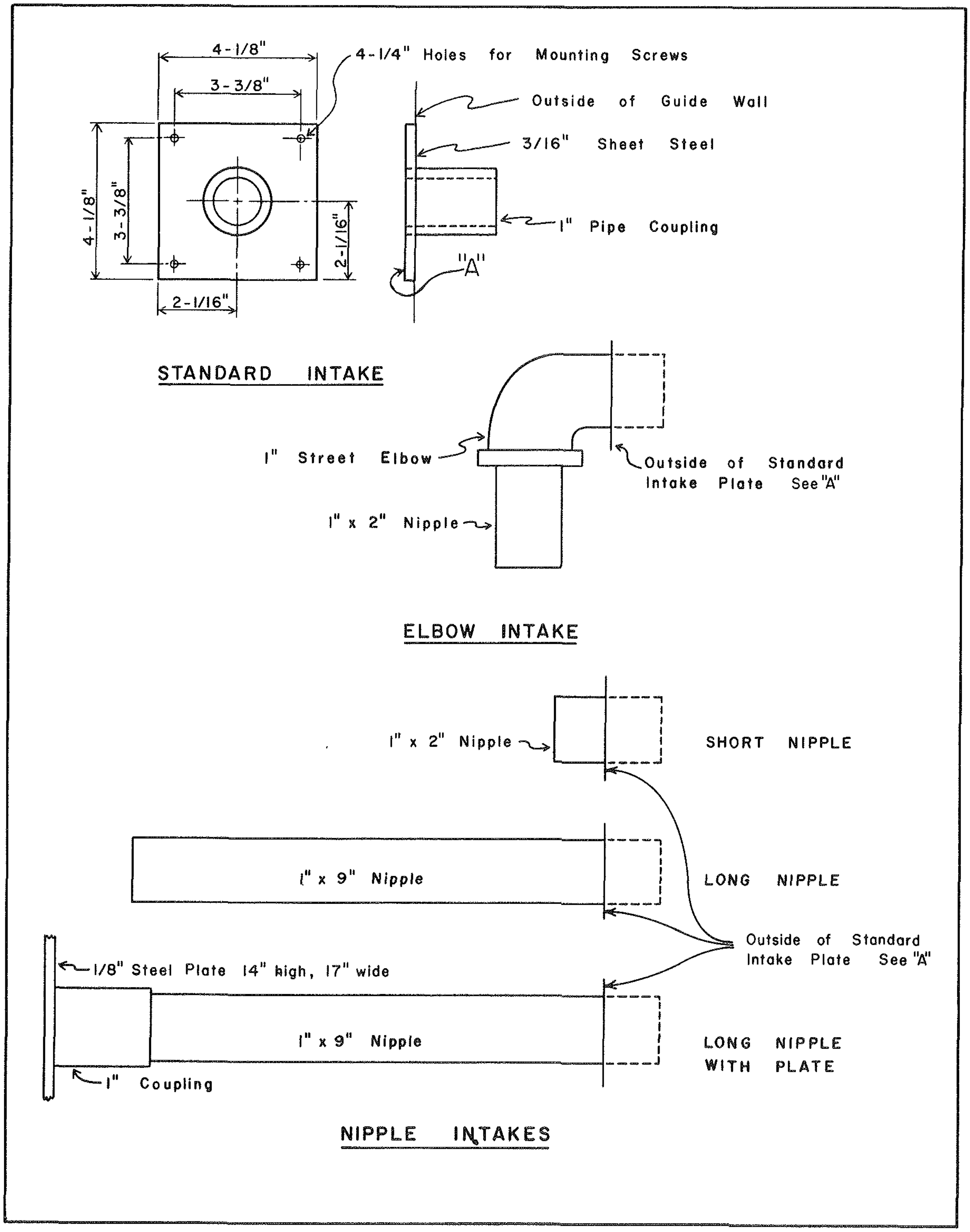


FIG. 10 - TYPES OF INTAKES TESTED

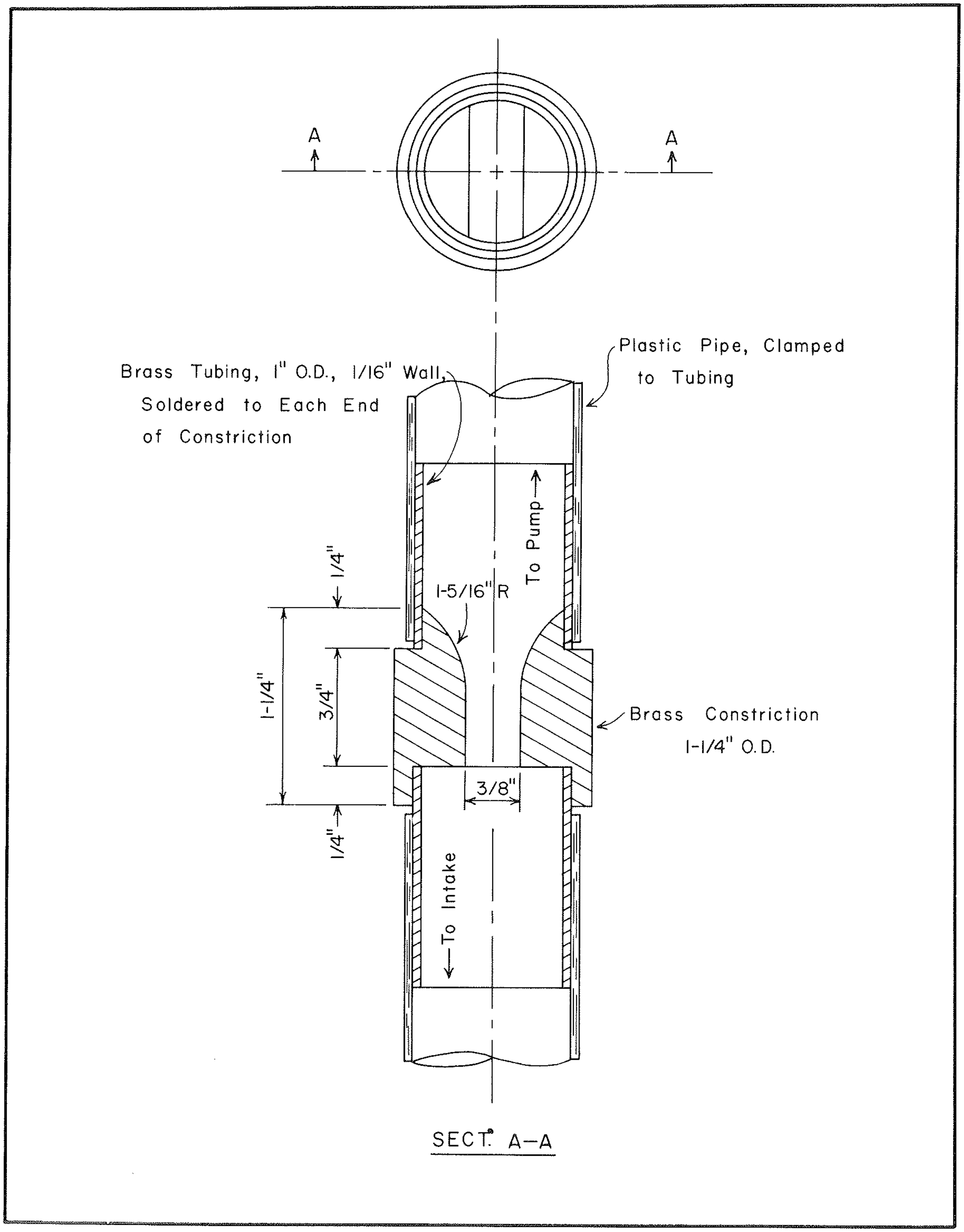


FIG. 11 – FISH TRAP

V. OPERATION OF INTAKE AND PUMPING SYSTEM

16. Period of operation--The intermittent pumping type sampler was first placed into operation September 2, 1957, and shut down on November 20, 1957. The system was reactivated during the periods of April 30 to October 8, 1958, and April 28 to October 26, 1959. Because of the 500 mile travel distance to the station and the expense of keeping the intake free of ice the system was not operated during the winter months.

17. The operational record--The operational record of the intermittent pumping sampler is shown in Table 2, which lists the periods and causes of operational failures. The first period of operation in 1957 (September 2-November 20, 1957) was to check the general operation of the system. There were two periods of operational failures. The first failure was caused by a malfunction in the sedimentation tank water level control. An early winter freeze and heater failure caused the second operational failure.

During the 1958 season (April 30-October 8, 1958) the sampler operated 123 days of the 162 day period for a 76 percent record. There were six periods of operational failure. Three of the failures were due to fish that entered the intake pipe. The fish either caught on the check valve and stopped the flow to the pump or entered the pump and damaged the impeller. The other three failures were caused by the shifting of the river bed which covered the intake with sediment. The station was visited only every 2 or 3 weeks. However, most of the failures occurred just preceeding the servicing periods, and the length of the failure period was usually short.

During the 1959 season (April 28-October 26, 1959) the intermittent pumping sampler was in operation only 77 days of the 182 day period for a 42 percent record. There were seven operational failures. The first failure was caused by a fish that entered the intake. Five failures were caused by silt that covered the intake and one failure was caused by a malfuction of the silt pump relay. Unlike the 1958 period of operation, failures occurred soon after servicing visits to the station and failure periods were long. During most of the season the water discharge was low and tended to shift towards the left bank. The low water discharge past the intake structure was not sufficient to prevent the silting of the intake opening.

TABLE 2 - OPERATIONAL RECORD OF THE INTERMITTENT PUMPING SAMPLER

	1957 (Sept. 2-Nov. 20)			1958 (Apr. 30-Oct. 8)							1959 (Apr. 28-Oct. 26)						
DAY	SEPT.	OCT.	NOV.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.
1					*	F		P				F	S	S	S		S
2	*	FC				F		P				F	S	S	S		S
3	*	FC	H			*		P				F	*	S	S		S
4		FC	H			*		P	S			F		S	*	R	S
5		FC	H			*		P	S			F		S	*	R	S
6		FC	H					P	S			F	*	S	*	R	S
7		FC	H				S	P *	S	*		F	*	S		R	*
8		FC	H				*	P *	S	S *		F	S	S		R	*
9		FC	H				*	*	S			F	S	S		R	*
10		FC	H				*		S			F	S	S		R	
11		FC	H						S			F	S	S		R	
12		FC	H						S			F	S	S		R	
13		FC	H		*				S			F	S	*		R	
14		FC	H		*				S			F	S	*		R	
15		FC	H						S			F	S	*		R	
16		FC	H		*				*			F	S			*	
17		FC	H			*			*			F	S			*	
18		FC	H			*			*			F	S			*	
19		FC	H			*						*	S	S			
20		FC	H *									*	S	S		S	
21		FC						F				*	S	S	*	S	
22		*					F	F					S	S	*	S	
23		*					P *	F					*	S	*	S	
24		*					P *	F				S	*	S	*	S	
25							P *	*				S		S		S	
26							P	*				S	S	S		S	*
27							P	*				S	S	S		S	
28							P				*	S	S	S		S	
29							P				*	S	S	S		S	
30				*			P				*	S	S	S		S	
31					F		P					S		S			
Operating days																	
Monthly total	29	11	2	1	30	28	20	19	18	7	3	5	8	6	28	7	20
Accumulative	29	40	42	1	31	59	79	98	116	123	3	8	16	22	50	57	77
Calandar days																	
Accumulative	29	60	80	1	32	62	93	124	154	162	3	34	64	95	126	156	182

Sampler shut down

CAUSES OF OPERATIONAL FAILURES

FC	Float control not operating	P	Pump overhaul
H	Water in pump froze because of heater failure	R	Silt pump relay stuck
F	Fish entered intake	S	Intake silted in

* Personnel at station

18. Evaluation of operational record--A few minor modifications in the original design of the pumping system were made as a result of experience. The original float control had a tendency to stick near the upper limit switch preventing the completion of the splitter cycle. Preceding the 1958 season the float control was modified to eliminate this source of failure.

The safety switch (described in Section 9) was installed on July 23, 1958. Before that time the silt pump operated without sufficient water when the intake was obstructed. A number of pump impellers were damaged and in one case, July 22, the pump shaft was damaged so that the pump had to be brought back to the laboratory for repairs. The addition of the safety switch prevented any further pump damage. An extra supply of impellers is maintained so that worn impellers may be changed at the sampling site.

The latest pumping system failure (September 4, 1959) was caused by the silt pump relay sticking closed. The present relays are used near load capacity. Continual operation near load capacity or occasional overloading damaged the relay contacts and caused the relay to stick in the closed position. The use of higher capacity relays should correct this difficulty.

Fish in the intake and silt covering the intake opening have caused operation failures. A number of devices to prevent the fish from entering the intake were considered. An electric fish repelling device to be mounted on the intake guide wall was designed by the U. S. Fish and Wildlife Service. This was not used because of possible safety hazards. An intake guard of coarse wire screen was tried but it soon became clogged with grass and straw. Then the plastic pipe was clamped about five feet from the river intake to form a slit 3/8 inch wide. This was later replaced by the fish trap described in Section 15. The trap has prevented fish from harming the pumping system.

Three intakes were mounted in the face of the guide wall to provide adjustment of the intake elevation as the river bed shifted. The intake can be easily adjusted to the desired elevation at the time the station is inspected but silting in the intake can occur between inspection trips. In a deep river the intake can be placed far enough from the river bed to assure continual operation, but the use of the present intake structure in a shallow shifting river requires frequent inspection to prevent operational failure.

VI. SAMPLING EFFICIENCY

19. Procedure--A series of tests were made to determine the sampling efficiency of the intermittent pumping sampler. Samples were collected and analyzed to determine (1) the length of time the splitter should remain in the presampling or waste position, (2) the relationship of the sediment concentration of the river at the intake to that of the pumped sample, (3) the relationship of the concentration of the river at the intake to the average concentration of the river at the gaging station, and (4) the concentration of the flush pump discharge.

20. Splitter tests--Three sets of samples were collected at the splitter discharge to determine the length of time required for the silt pump to obtain a representative sample. The first sample in each of the three sets was collected 5 seconds after the silt pump started. Additional samples were collected at 10 to 30 second intervals during a period of about 2 1/2 minutes. The results of these tests are shown in Table 3.

TABLE 3

LAG IN SAMPLE CONCENTRATION AT SPLITTER
[in ppm]

Time delay secs	Sample Concentration			
	5/14/58 10:00 am	5/14/58 2:05 pm	7/9/58 6:30 pm	
0				
5	43	352	2,920	Time delay is from time pump started to start of sample. Sampling time about 5 secs per sample.
10			6,510	
15	379	556		
20			8,950	
25		1,710		
30	454		8,990	
35		1,780		
45		1,780	9,030	
60	448	1,730	9,060	
75		1,770	9,020	
90	442	1,800	9,030	
105		1,740	9,050	
120	465	1,770	9,090	
135		1,770		
150	453	1,820		
165		1,720		

In each of the tests the sediment concentration of the splitter discharge became constant about 30 seconds after the silt pump started. As a result of these tests the pumping controls are set so that the splitter remains in the presampling or waste position for 50 seconds.

21. St. Paul intake tests--Samples were collected periodically in the river at the intake with a DH-48 suspended sediment sampler and from the splitter discharge to determine the relationship of the concentration of the pumped sample to that of the river at the intake. The one inch flush opening (standard intake) as well as the modified intakes, shown in Fig. 10, were tested.

The average velocity of the river at the intake is about 1.40 ft per sec. The velocity of the pumped sample through the intake opening is about 4.40 ft per sec. This gives a velocity ratio of 3.14. The suspended sediment flow in the North Loup River past the gaging station is described in Section 6.

The results of the standard intake tests are shown in Fig. 12 and in Appendix , Table 10. The concentration of the river samples ranged from 164 ppm to 20,900 ppm. Equal concentrations are shown by the diagonal line. The concentration ratio (splitter concentration/river concentration) ranged from 0.94 to 1.11. Size analyses of samples taken using the standard intake show that the size distribution of the suspended sediment in the pumped sample agrees very closely with the suspended sediment content of the river at the intake.

The results of the modified intake tests are shown in Fig. 13 and 14 and Appendix, Tables 11 & 12. The modified intakes could not be tested in high river concentrations because the intake structure is not sufficiently accessible during periods of high flow. The concentration ratios ranged from 0.94 to 1.10.

Results from the St. Paul intake tests at the station site indicated that the standard intake is the best because its sampling efficiency is as good as that of the modified intakes and it is less likely to catch river debris.

22. Dunning intake tests--A portable pumping system was operated at the turbulence flume on the Middle Loup River at Dunning, Nebraska, to test the various types of intakes in coarser sediment flow. The

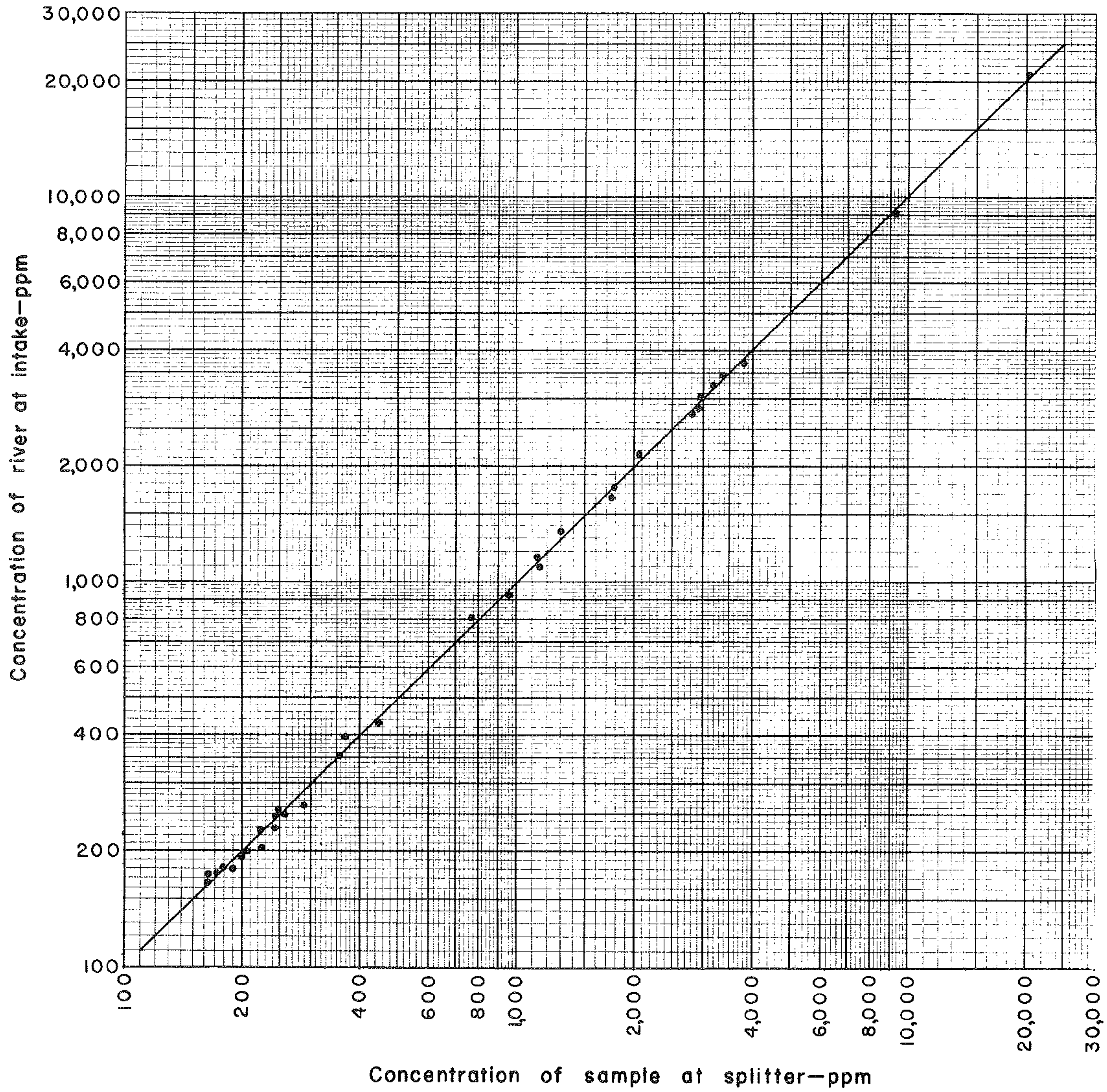


FIG. 12—RESULTS OF STANDARD INTAKE TESTS

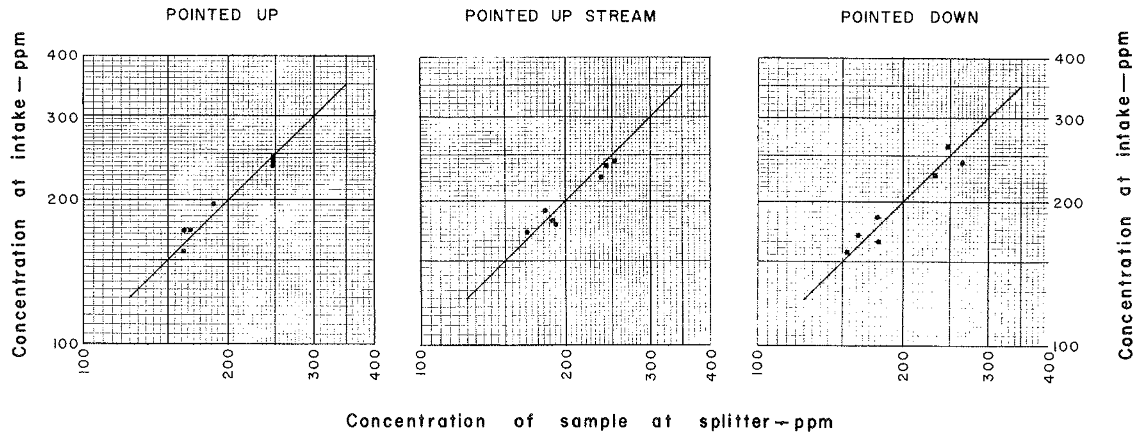


FIG. 13 - RESULTS OF ELBOW INTAKE TESTS

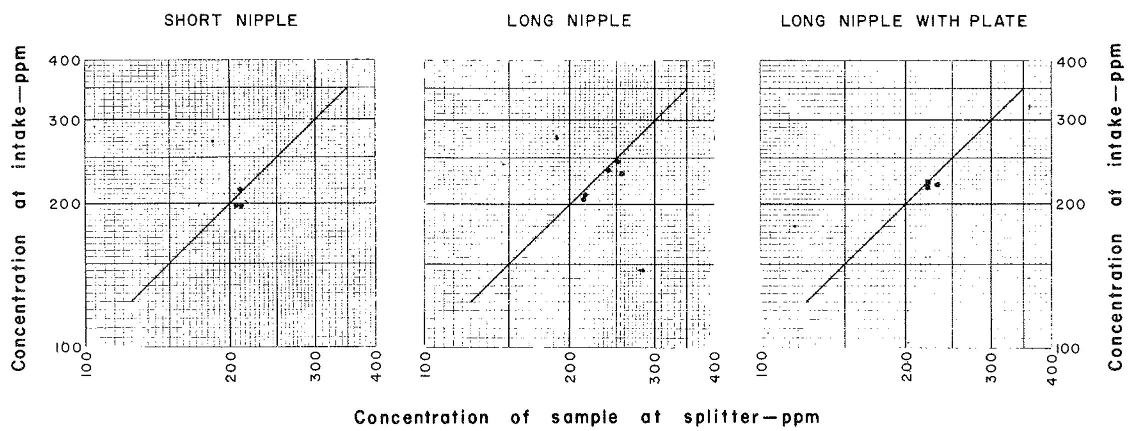


FIG. 14 - RESULTS OF NIPPLE INTAKE TESTS

turbulence flume is a structure for inducing turbulence sufficient to suspend substantially the total sediment load of a stream.1/ A 10 foot, 2 x 12 in. board was mounted on the bridge pilings to form a guide wall. The end of the guide wall was extended downstream from the pilings so that the intake mounting was directly above the measuring sill. The suction line to the pump was a 1 in. plastic pipe 50 ft long. Flow was controlled by a manual pinch valve on the discharge port of the pump. The total depth of water at the intake was 1.2 feet and the intake was located 0.5 feet above the measuring sill. The average water velocity at the sampling point was 4.92 ft per sec.

Size analyses of the sediment load passing the downstream side of the measuring sill of the turbulence flume at the sampling point show that about 10 percent is finer than 0.062 millimeter and 100 percent is finer than 1.0 millimeter. The median particle size is about 0.25 millimeter.

Results of the Dunning intake tests are shown in Table 4. The intakes tested were the same as those tested at the St. Paul installation with two additions. Besides the 1 in. (standard intake), a 2 in. and 1/2 in. openings in flat plates were tested. Above a velocity ratio of 0.60 the 1 in. flush opening (standard intake) had a concentration ratio of around 0.80 but dropped sharply as the velocity ratio fell below 0.60. The 2 in. flush opening maintained a high concentration ratio for the lower velocity ratios. Although many more tests should be made before any definite conclusions can be made, it seems that a sampling efficiency above 80 percent could be obtained for most river conditions.

23. Relation of river concentration to concentration at intake--Depth integrated suspended-sediment samples were taken at 20 or more verticals in the river cross section near the gaging station in conjunction with samples of the river at the intake at various times throughout the period of sampler operation to determine the relationship of the concentration of the river at the intake to the average concentration of the river in the cross section at the gaging station. The cross section samples were collected by wading near or at the sampler intake or from the downstream side of the highway bridge.

1/ Hubbell, D. W., and Matejka, D. O., 1959, Investigations of Sediment Transportation Middle Loup River at Dunning, Nebraska: U. S. Geological Survey Water Supply Paper 1476, p 11-12.

TABLE 4

INTAKE TESTS AT DUNNING, NEBRASKA
[Samples collected 6/5/59]

Intake	Time	Intake Velocity (ft/sec)	Velocity Ratio (1)	Pumped Sample (ppm)	River Sample (ppm)	Ratio (2)
1" Flush opening (Standard intake)	11:20 am	6.96	1.41	2,140	2,845	0.75
	2:25 pm	6.96	1.41	1,770	2,170	0.82
	3:55 pm	6.96	1.41	1,320	1,720	0.77
	11:55 am	3.18	0.65	1,650	1,800	0.92
	2:30 pm	2.67	0.54	1,880	2,680	0.70
	3:58 pm	3.47	0.70	1,420	1,720	0.83
	4:02 pm	1.82	0.37	994	1,720	0.58
	4:05 pm	1.44	0.29	717	1,720	0.42
2" Flush opening	3:05 pm	2.27	0.46	1,290	1,870	0.69
	3:10 pm	0.81	0.16	1,280	1,780	0.72
1/2" Flush opening	3:35 pm	20.94	4.26	977	1,960	0.50
	3:40 pm	9.62	1.96	997	2,020	0.49
1" x 2" Nipple	1:15 pm	10.45	2.12	1,040	859	1.21
	1:20 pm	4.00	0.81	765	967	0.79
1" x 9" Nipple	1:30 pm	10.45	2.12	719	830	0.87
	1:35 pm	4.00	0.81	750	989	0.76
1" El. pointed Downstream	1:40 pm	10.45	2.12	686	960	0.71
	1:45 pm	4.36	0.89	842	975	0.86
1" El. pointed Upstream	1:50 pm	10.45	2.12	1,460	1,670	0.87
	1:55 pm	4.00	0.81	1,070	980	1.09
1" El. pointed Up	2:00 pm	10.45	2.12	1,130	1,140	0.99
	2:05 pm	4.36	0.89	1,120	1,040	1.08

(1) Intake velocity divided by 4.92 (average velocity of river at sampling point).

(2) Concentration in pumped sample divided by concentration in river sample.

The results of the cross section samples are shown in Table 5.

TABLE 5

CROSS SECTION SAMPLES NORTH LOUP RIVER NEAR ST. PAUL, NEBRASKA

Date	Cross Section Samples			Intake Samples		Conc.
	Time	Location	Avg. Conc. (ppm)	Time	Conc. (ppm)	Ratio (1)
6/9/58	10:45 am	Bridge	278	11:55 am	280	0.99
6/17/58	5:15 pm	S.W. gage	302	5:25 pm	236	1.28
6/23/58	12:30 pm	Bridge	291	1:50 pm	225	1.29
7/7/58	6:10 pm	Bridge	771	7:05 pm	747	1.03
7/9/58	3:00 pm	Bridge	11,200	4:45 pm	10,200	1.10
8/18/58	12:30 pm	Bridge	150	1:10 pm	155	0.97
8/26/58	1:50 pm	S.W. gage	311	2:10 pm	218	1.43
6/3/59	1:15 pm	Samp.Intake	246	1:35 pm	208	1.18
6/24/59	10:35 am	Samp.Intake	543	10:45 am	414	1.31
8/22/59	1:35 pm	Samp.Intake	166	1:40 pm	127	1.31

(1) Conc. ratio is the average cross section conc./intake conc.

Concentration of the cross section samples ranged from 150 ppm to 11,200 ppm. The concentration ratio ranged from 0.97 to 1.43 and averaged 1.19. The three measurements which had concentration ratios greater than 1.30 were made during periods of low flow when the main flow had moved away from the south bank and the pumping sampler intake.

24. Flushing water tests--Periodic samples of the flush pump discharge were collected to determine the amount of suspended sediment pumped from the sedimentation tank. The results of the analysis of these samples are shown in Table 6. The sediment loss of the 11 tests ranged from 11 to 36 percent. The average loss was 23 percent.

When the pumped sample enters the sedimentation tank some of the fine sediment is raised up toward the water surface by the water circulation. This fine sediment does not settle below the elevation of the flushing water inlet pan (about 10 inches) during the 25 minutes between pumping cycles. The addition of a flocculating agent would decrease the settling time of these fine sediments and reduce the sediment concentrations in the flushing water.

TABLE 6

FLUSHING WATER TESTS

Date	Time	Intake Samples		Flushing Samples		Percent Loss
		No.	Avg. Conc. (ppm)	No.	Avg. Conc. (ppm)	
8/26/58	11:25 am	3	221	6	78	35
do	1:25 pm	3	224	3	77	34
do	2:25 pm	3	222	3	80	36
9/17/58	1:00 pm	3	364	3	63	17
do	1:30 pm	3	366	3	72	20
6/3/59	2:05 pm	2	204	2	34	17
6/7/59	2:10 pm	2	178	2	54	30
6/23/59	2:40 pm	2	1,180	2	128	11
6/24/59	11:10 am	2	418	2	66	17
10/8/59	9:15 am	2	1,340	2	265	20
do	4:45 pm	2	808	2	98	12
					Avg. loss	23

VII. RECORDING SYSTEM

25. Operation--The recording system shown in Figs. 4 and 8, records the accumulated weight of the sediment. The sediment deposits on a weighing pan suspended near the bottom of the sedimentation tank. A load measuring device is placed between the hoist and weighing pan and the accumulated load is recorded by a line graph recorder.

26. Weighing pan--The aluminum weighing pan, shown in Fig. 8 and 15, is 4 feet square and 3 feet deep. An I-beam and chain cradle suspension connects the weighing pan to the hoist. Roller guides mounted on the sides of the sedimentation tank reduce friction between the weighing pan and sedimentation tank.

The hoist is connected to an I-beam trolley so that the weighing pan can be moved outside the shelter. One side of the weighing pan is hinged at the top so that it can be opened to dump sediment.

27. Baffles--Four sheet metal baffles direct the suspended sediment into the weighing pan. (See Fig. 8.) The baffles are connected at the edges to form an open end box 3 feet square and 3 feet deep. Three baffles contain a series of small openings just below the water surface to prevent circulation under the baffles when water is entering or leaving the sedimentation tank.

28. Crane scale--The crane scale, shown in Fig. 16, is an electrical load pick-up device. It contains a load sensitive column to which are bonded four resistance wire strain gages. These gages form an electrical balanced-resistence bridge. The load sensitive member and strain gages are enclosed in a tubular shell. The shell and load sensitive member are screwed and pinned to an eye at one end and a swivel hook at the other. A four wire cable connects the crane scale to the recorder.

The circuit diagram of the crane scale is shown in Fig. 17. When a load is lifted, the strain causes a resistance change in the strain gages which unbalances the bridge. The recorder supplies a fixed voltage to the crane scale bridge and the output voltage is proportional to the bridge unbalance and also to the load.

The load capacity of the crane scale is 2,500 pounds with a maximum deflection of 1/16 of an inch.

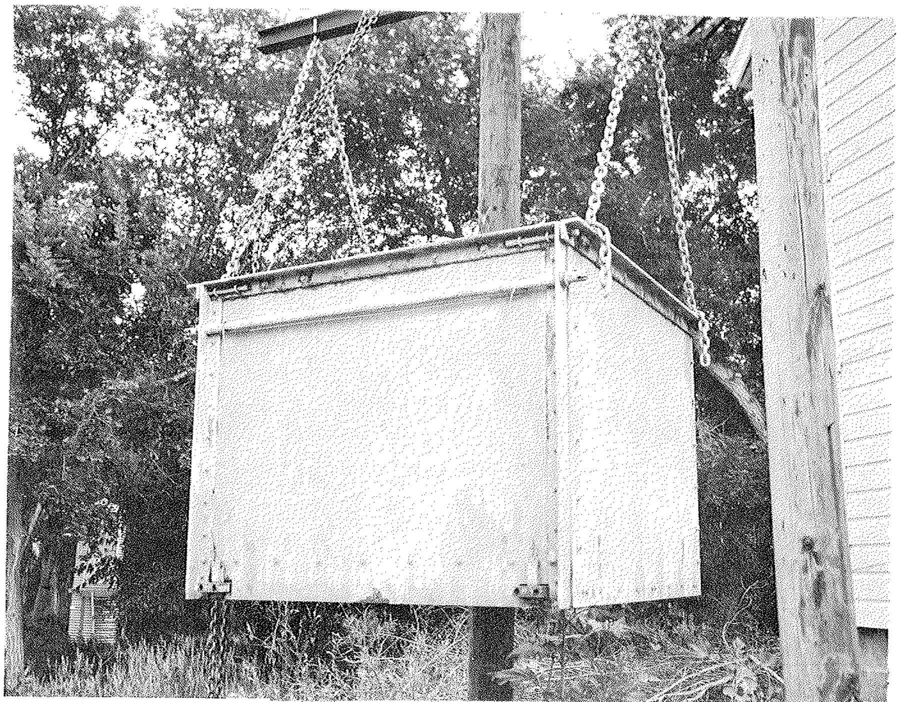


Fig. 15A

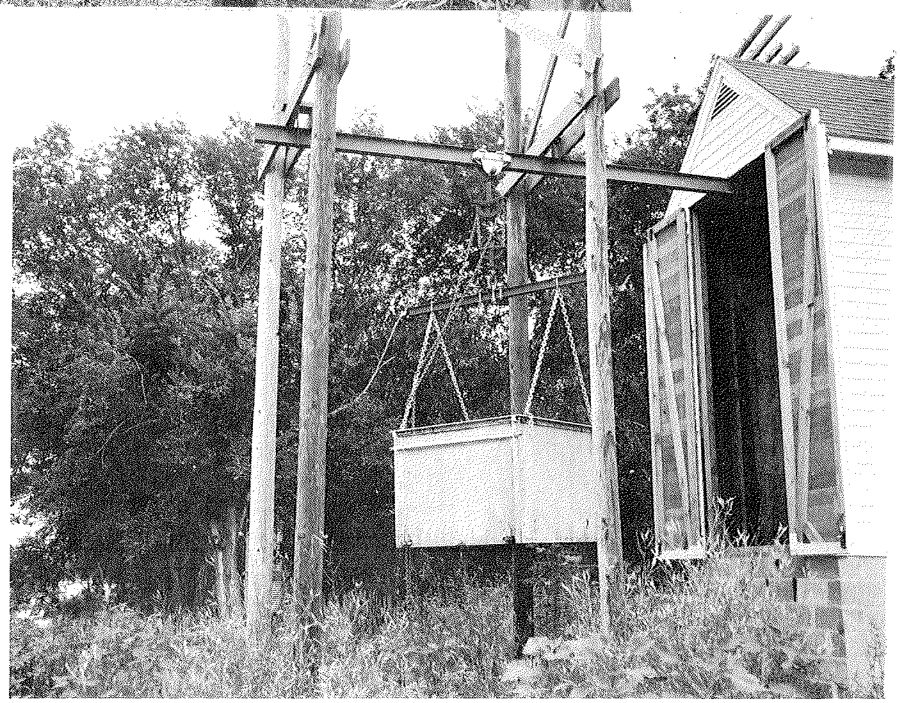
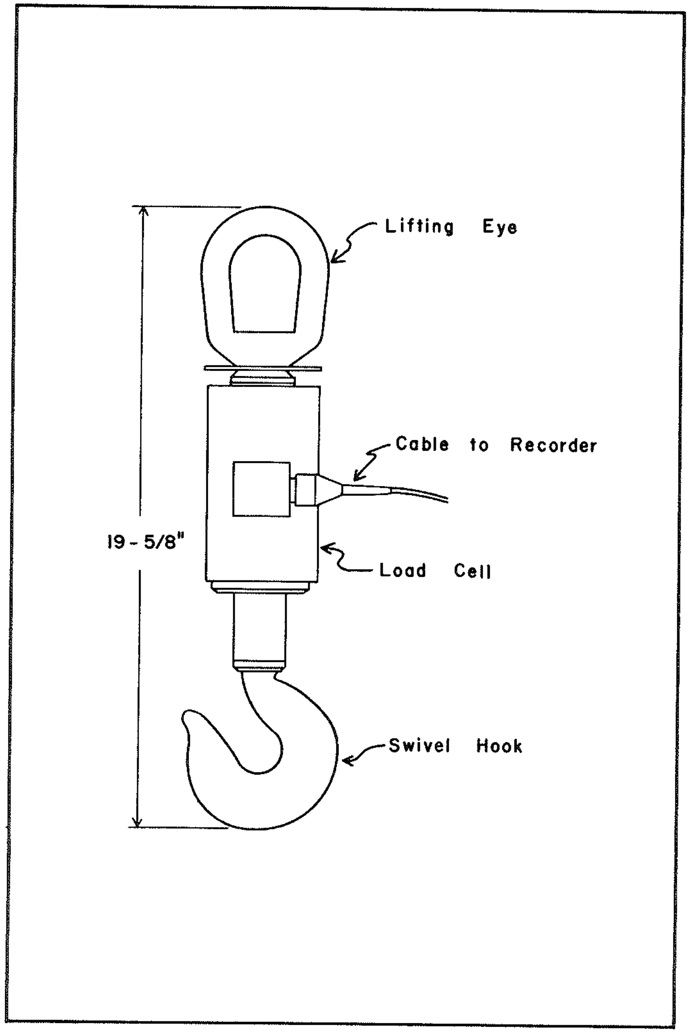


Fig. 15B

Fig. 15 - WEIGHING PAN



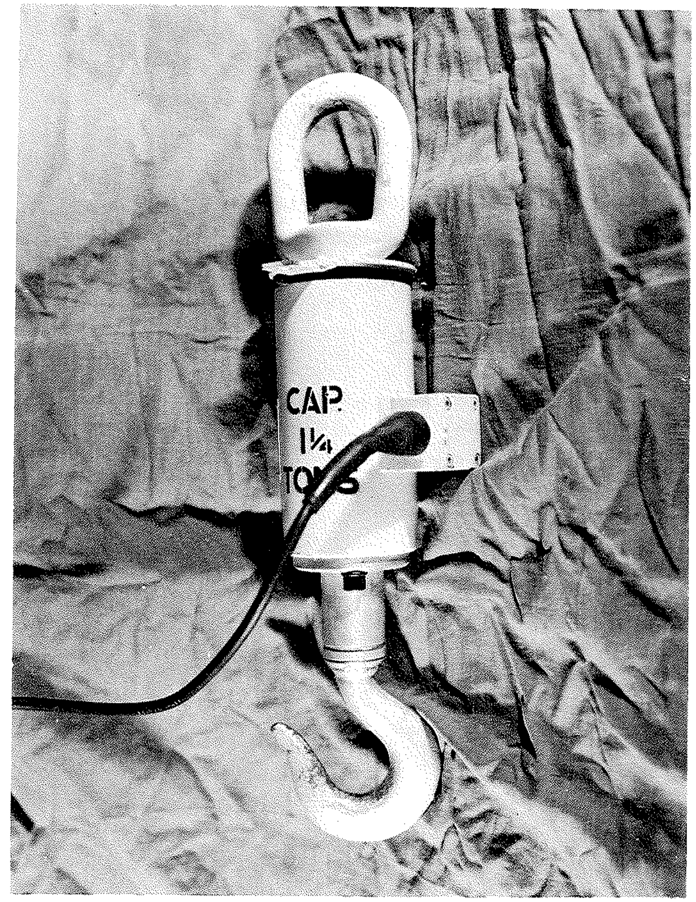


FIG. 16 - CRANE SCALE

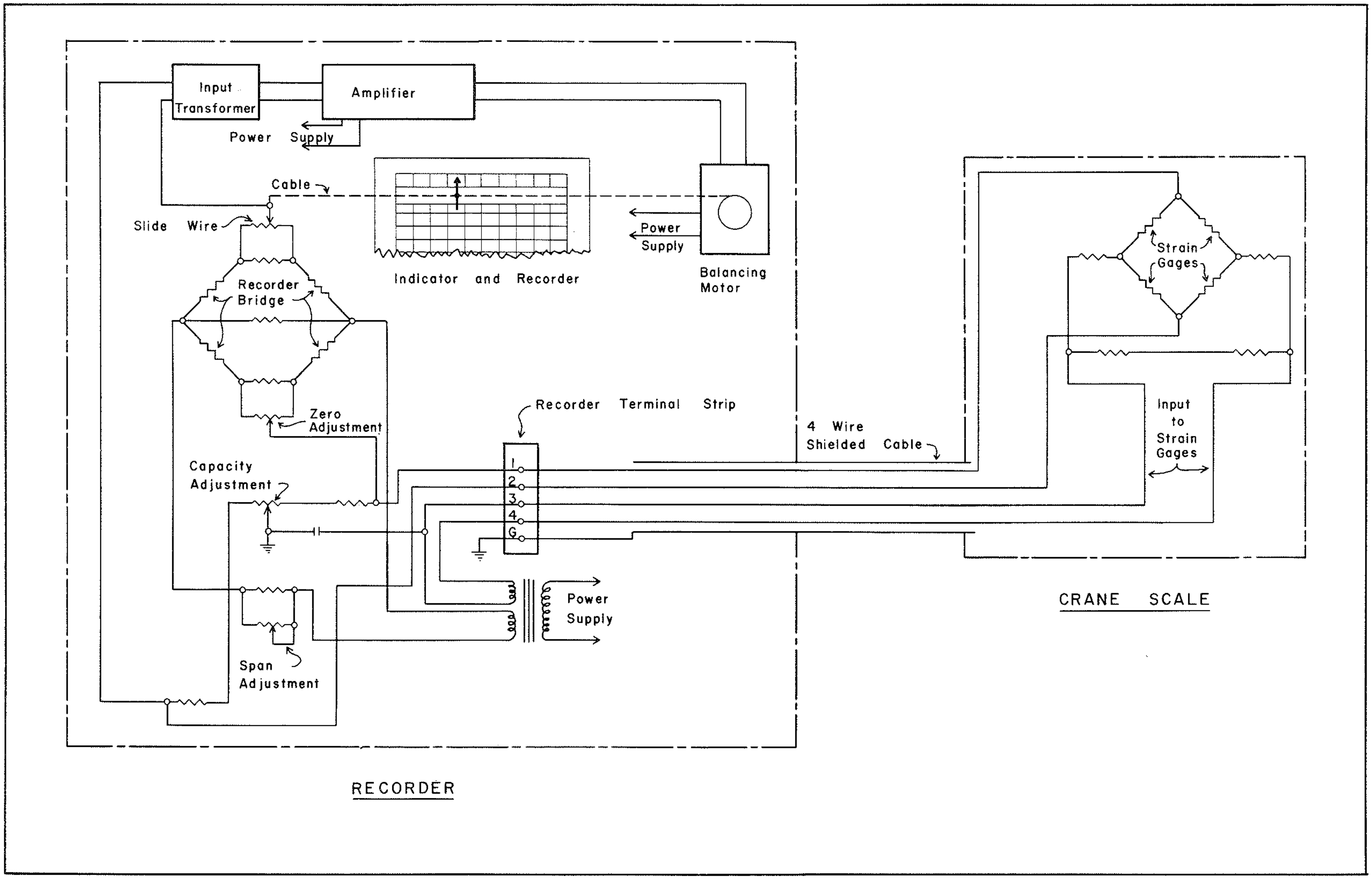


FIG. 17 – RECORDER AND CRANE SCALE CIRCUIT DIAGRAM

29. Recorder--The recorder, shown in Fig. 18, is a wide strip chart recorder consisting basically of an automatic null-balancing measuring curcuit with its power supply, a pointer indicator, and a recording pen.

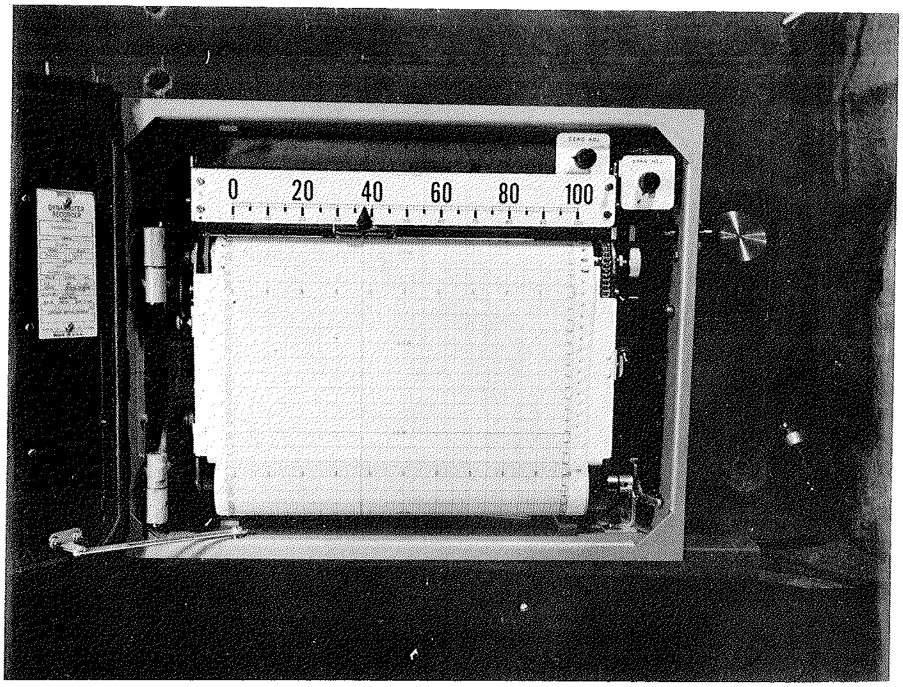


FIG. 18 - RECORDER

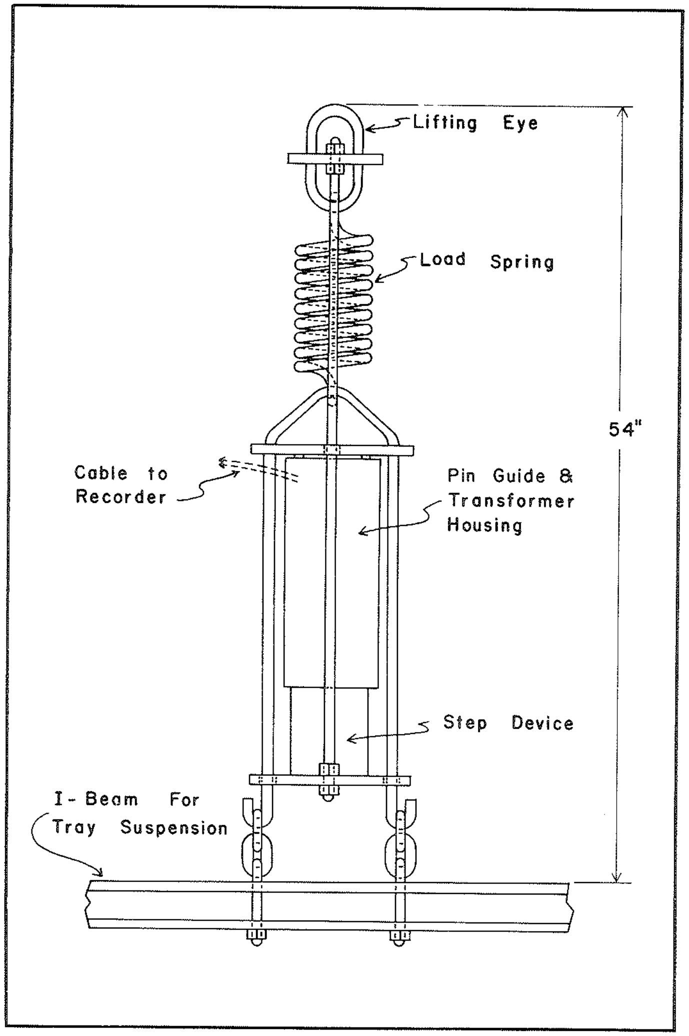
The circuit diagram of the recorder has been shown in Fig. 17. The power supply energizes the internal recording bridge as well as the crane scale bridge. The output voltage from the two bridges is compared in the instrument. The difference between the two output voltages is amplified and used to drive a balancing motor which in turn drives a slidewire contact arm in such a direction as to reduce the difference to zero. The slidewire constitutes one leg of the instrument bridge measuring circuit, and consequently the bridge output voltage is proportional to the slidewire contact position. The pointer indicator and recording pen are mechanically linked to the slidewire and the strip chart is graduated so that, at the balance position, the indicator and pen reading is equal to the load on the crane scale.

30. Spring-transformer scale--The crane scale was replaced by the spring and transformer unit shown in Fig. 19. It contains a coil extension load spring, linearly-variable differential transformer, and a transformer core stepping device. The load spring has a 1,400 pound load capacity and a deflection of about 1/4 inch per 100 pounds. The differential transformer measures the deflection of the load spring in 1/4 inch or about 100 pounds increments. The deflection measuring increments are controlled by the transformer core stepping system shown in Fig. 20. When an accumulative load builds up on the spring-transformer scale the transformer housing and pin guide move downward toward the base plate. The transformer core leaves the center or zero position and approaches the top of the transformer. After the transformer housing and pin guide have traveled 1/4 inch the pin guide clears the top pin allowing the pin to trip to its outer position. The step rod will then drop 1/4 inch to the next lower pin which drops the transformer core back to the zero position. This operation continues for the 12 remaining pins.

The circuit diagram of the spring-transformer scale is shown in Fig. 21. The linearly-variable differential transformer is an electromechanical transducer which produces an electrical output proportional to the displacement of a movable core. It consists of a number of coils axially spaced on a cylindrical coil form with a rod-shaped magnetic core inside the coil assembly to provide a preferred path for the magnetic flux between the coils.

When the primary or center coil is energized with alternating current, voltages are induced in the secondary or outer coils. The secondary coils are connected in series opposition, so that the two voltages in the secondary circuit are opposite in phase. The net output of the transformer is the difference of these voltages. When the core is in the center position the output voltage is zero. As the core is displaced from the center position the induced voltage is increased in the coils toward which the core is moved, while the voltage induced in the opposite coil is decreased. This produces a differential voltage output from the transformer which varies linearly with the change in core position. Only the upper half of the core movement is used in the spring-transformer scale.

Two 2-wire-shielded cables connect the spring transformer scale to the recorder. The recorder supplies a fixed voltage to the differential transformer and the output voltage is fed back to the recorder through a



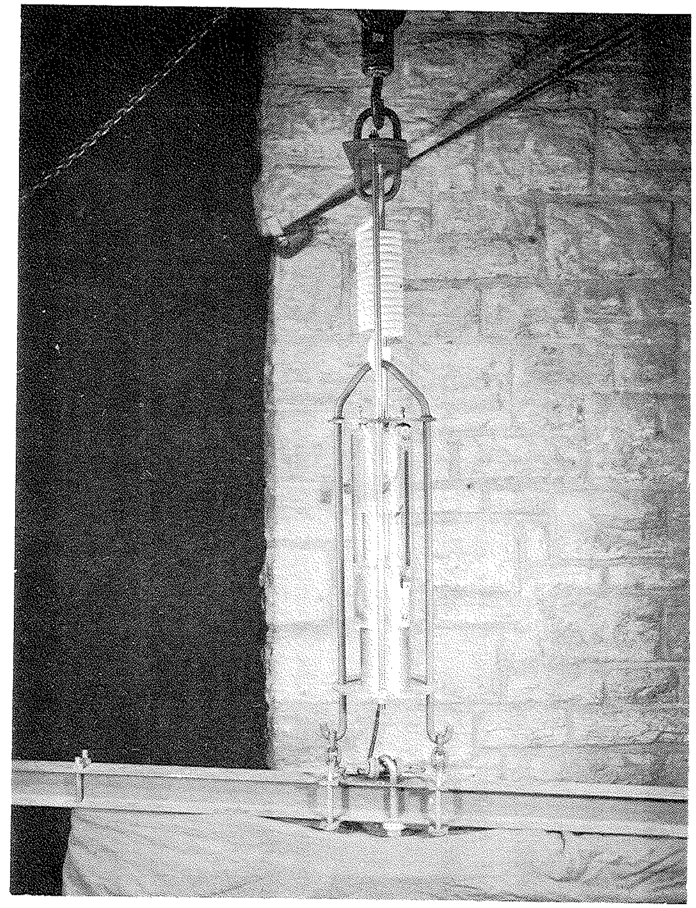
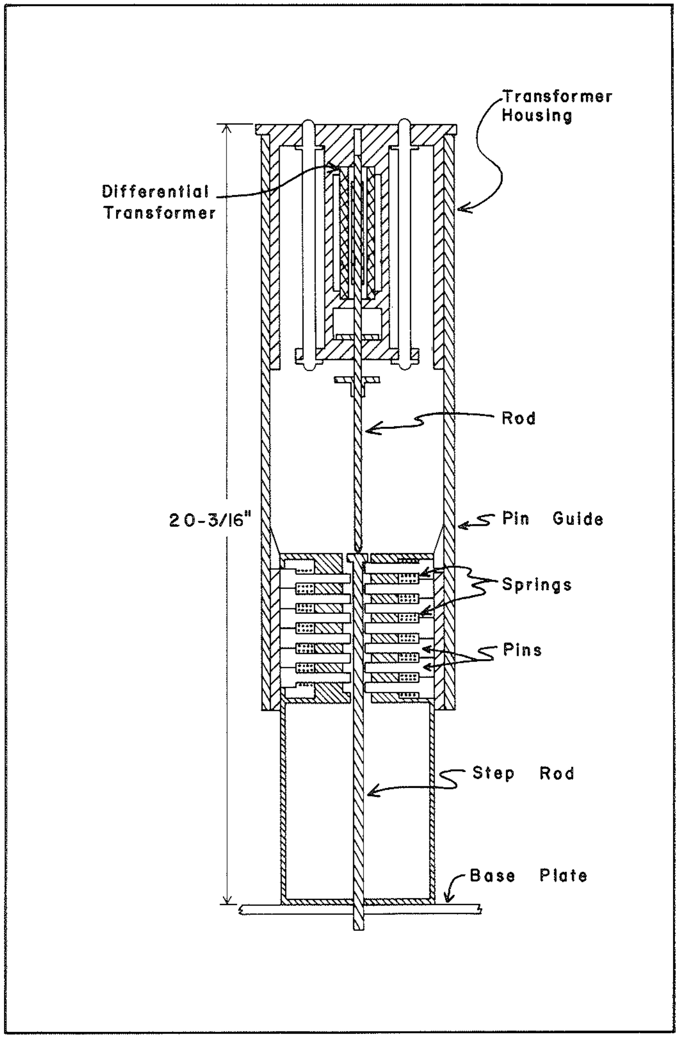


FIG. 19 - SPRING — TRANSFORMER SCALE



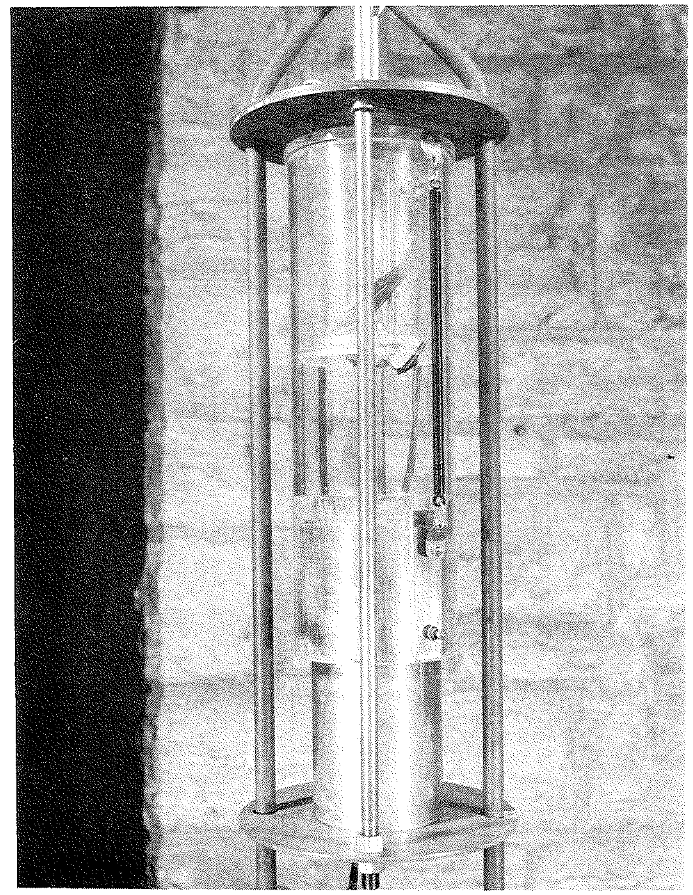


FIG. 20 - STEPPING SYSTEM FOR SPRING-TRANSFORMER SCALE

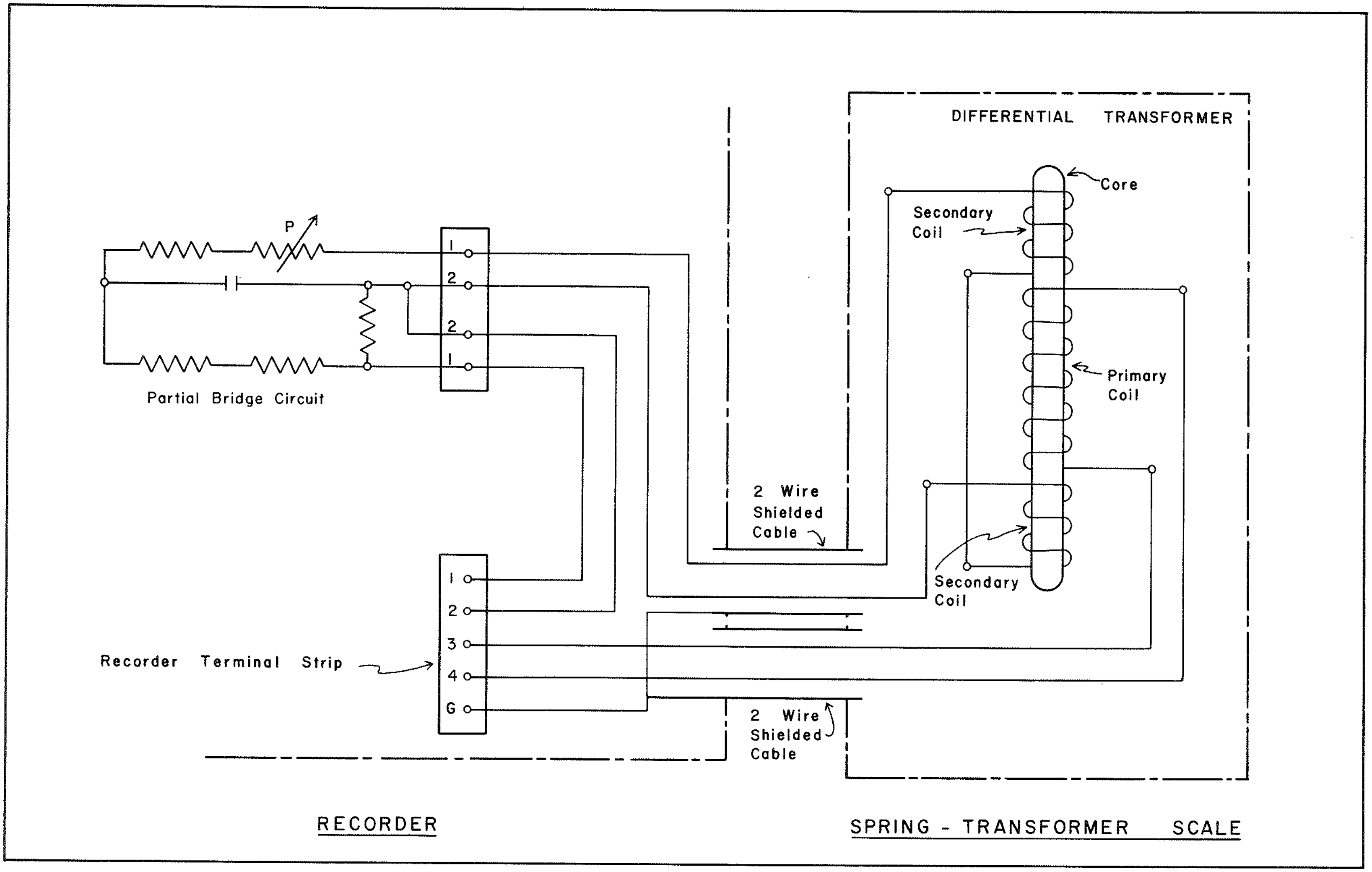


FIG. 21 - SPRING - TRANSFORMER SCALE CIRCUIT DIAGRAM

partial bridge circuit. This circuit cuts down the output voltage and changes phase to match the recorder bridge. Movement of the transformer core unbalances the output voltages between the differential transformer and recorder bridge. The difference between the two output voltages is amplified and used to drive the balancing motor which in turn drives the slidewire contact arm in the direction that reduces the difference to zero.

A 1/4 inch movement of the differential transformer core moves the recorder indicator and pen full scale range which indicates 100 pounds of load on the spring-transformer scale. Therefore after each 100 pounds of accumulative loading, the recorder indicator and pen drop back to the zero reading. The total load on the spring-transformer scale is the reading on the recorder plus 100 times the number of pins tripped in the transformer core stepping system.

VIII. OPERATION OF RECORDING SYSTEM

31. Determination of sediment concentration--The concentration of suspended sediment in the pumped sample is equal to-

$$C = \frac{D_W}{P} \times 10^6 \qquad \text{equation 1}$$

where-

C is the average concentration of suspended sediment (ppm) for a given period of time.

D_W is the dry weight of the suspended sediment (lbs) for the time period.

P is the total weight (lbs) of the pumped sample for the time period.

Because the weighing pan is suspended in water the submerged or "wet" weight of the sediment is recorded. The dry weight of the sediment is-

$$D_W = \frac{2.65}{1.65} \times W_W = 1.606 \times W_W \qquad \text{equation 2}$$

where-

W_W is the submerged weight of the sediment.

For any given period of time the submerged weight of the sediment is the difference between the recorder readings at the beginning and end of the measuring period. Substituting the submerged weight of the sediment in equation 1 -

$$C = \frac{1.606 W_W}{P} \times 10^6 \qquad \text{equation 3}$$

The average cross-sectional area of the sedimentation tank between the high and low water elevations was determined to be 21.79 sq ft. Periodic measurements of the high and low water elevations were made and the average difference was 0.174 ft. Therefore the average volume of the pumped sample is 21.79 x 0.174 or 3.79 cu ft. The weight of the pumped sample per cycle is 3.79 x 62.4 or 236 lbs. The total weight of the pumped sample will be -

$$P = 236N \qquad \text{equation 4}$$

where-

N is the number of pumping cycles during the measuring period.

The present intermittent pumping sampler has two pumping cycles per hour.

By substituting for P in equation 3 the average concentration of the suspended sediment in the pumped sample for a given period of time becomes -

$$C = \frac{1.606\ W_w}{236N} \times 10^6 \qquad \text{equation 5}$$

32. Operation of crane scale and recorder--The crane scale and recorder operated from October 23, 1957 through the remainder of the 1957 pumping sampler season, and through all of the 1958 pumping sampler season.

The load capacity of the crane scale is 2,500 pounds. Because the submerged weight of the weighing pan and suspension cradle is 325 lbs the system will weigh a sediment accumulation up to 2,150 lbs. The crane scale and recorder is sensitive to the nearest five lbs.

The recorder chart, Fig. 22, is a 120 ft strip chart 12 in. wide and has an 11 in. calibrated scale of 0-100. Therefore each line on the chart represents one percent of the 2,500 lb total load or 25 lbs. The chart can be read to the nearest five lbs. The chart speed is 3/4 in. per hour.

The first period of storm runoff during sampler operation was on July 9, 1958. Four-hour-average concentrations were computed from samples collected at the intake during the day, and from the recorder trace. These results are shown in Table 7. The sampling efficiency is expressed as the ratio of sampler concentration to concentration at the intake. Because the sediment discharge consisted mostly of finer than average material the 32 percent difference in the average daily concentrations agrees reasonably well with the flushing water tests, Section 24.

As the recorder trace is readable to the nearest 5 lbs, the actual weight may differ by 2 1/2 lbs. This represents a four-hour-average concentration of 2,120 ppm and a daily average concentration of 354 ppm.

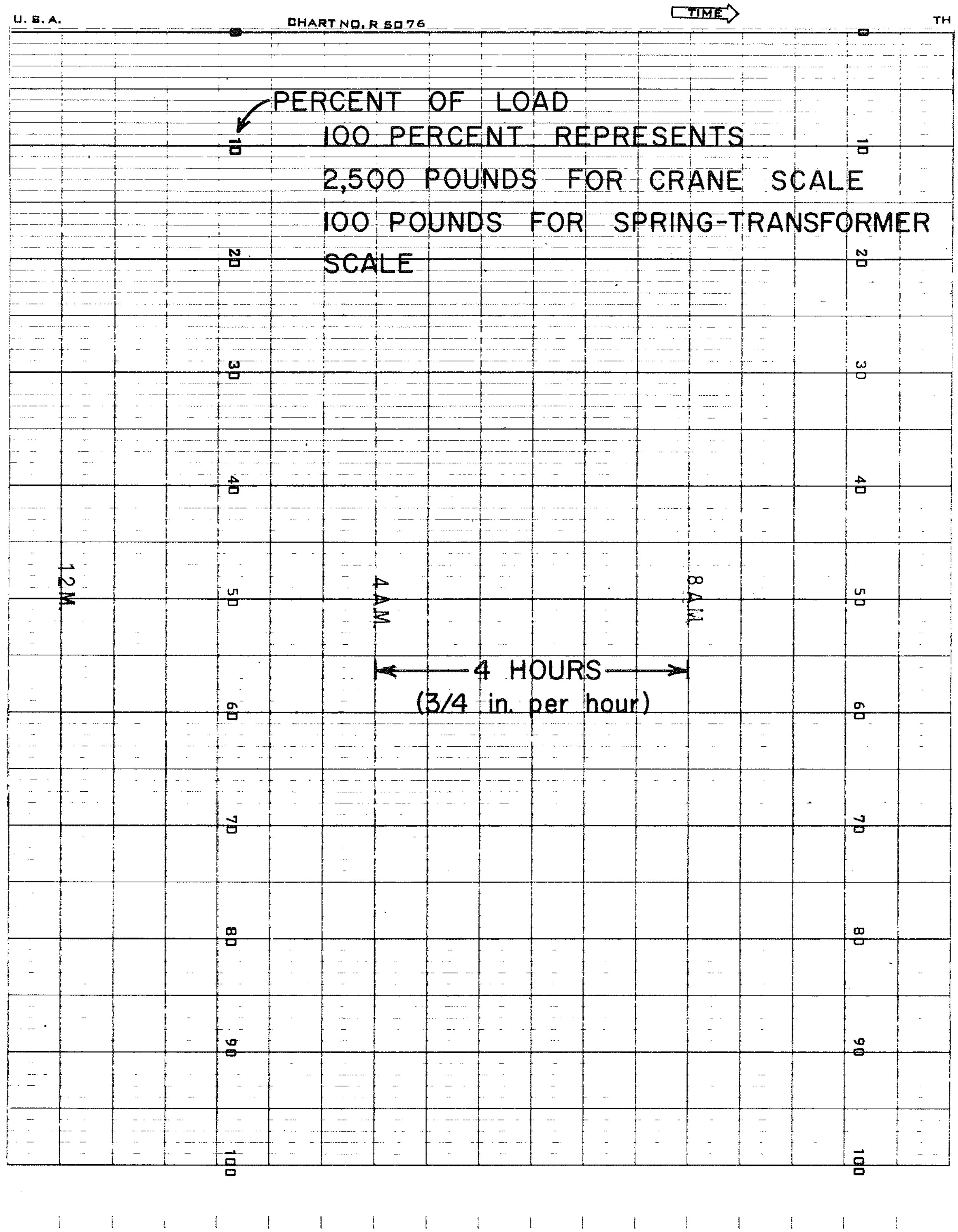


FIG. 22 – RECORDER CHART

TABLE 7

SAMPLING EFFICIENCY
July 9, 1958

Clock Time	Recorder Trace Reading (lbs)	Wet wt. Sediment added (lbs)	Concentration from Recorder (ppm)	Avg.Conc. from River Samples (ppm)	Sampling efficiency (percent)
12 am	410				
4 am	420	10	8,510	9,940	86
8 am	440	20	17,000	22,900	74
12 m	455	15	12,800	19,800	65
4 pm	465	10	8,510	12,500	68
8 pm	470	5	4,250	9,180	46
12 pm	475	5	4,250	7,020	60
Average for day			9,220	13,600	68

33. Operation of the spring-transformer scale--A more sensitive weighing system, the spring-transformer scale of Section 30, was designed so that the concentrations could be recorded more accurately and for shorter periods of time. A 1/4 in. deflection of the load spring represents 100 lbs of loading and full recorder span so the recorder chart reads from 0 to 100 lbs, Fig. 22. The scale is sensitive to the nearest one pound.

Due to the frequent operational failure of the intermittent pumping sampler and the low river discharge during the 1959 operating season the field testing of the spring-transformer scale was restricted to a short period of time and light loading. During part of the operating period the recorder trace was very unsteady. After the recorder was brought back to the laboratory at the end of the operation period a faulty wire connection was found in the recorder input circuit. Vibration of the recorder during periods of pump operation caused intermittent breaking of electrical contact at the faulty connection.

Daily air temperature fluctuations in the sampler shelter caused a variation in the recorder trace readings. The indicated load on the recorder was lowest during the afternoon maximum air temperatures. The maximum difference in recorder trace readings was 3 lbs which corresponded to a difference in air temperature of about 30 degrees.

IX. FUTURE PROGRAMMING OF INTERMITTENT PUMPING SAMPLER

34. Further work on present installation--Although the pumping system in the present installation has been reasonably satisfactory several modifications should be made to improve operation. When the intake is obstructed or the end is buried in sand the present safty switch on the splitter control, Section 9, shuts the system off and it remains off until manually restarted. Possible modification of the safty switch so that the system would reactivate itself if the intake is uncovered is being studied. Occasionally debris on the check valve obstructs the flow to the pump. The desirability of using a larger size or different type of check valve is to be studied. A study will be made to reduce the sediment removed from the sedimentation tank by the flushing water.

The limitations of the present intake structure were described in Section 17. Future work on the intake structure will be directed towards improvements that permit the intermittent pumping sampler to operate over longer periods of time with fewer inspections.

The weighing system was made more sensitive by the use of the spring-transformer scale. If practicable the scale will be improved to increase its sensitivity and eliminate the temperature effect.

35. Future installations--Future development of the intermittent pumping sampler will be directed towards adaptation to small or ephemeral streams. The first step will be to develop a portable sampler so that the representativeness of samples and the dependability of operation can be determined on a number of streams. The unit will have its own electric system.

The samples collected by the first portable intermittent pumping sampler will be collected in bottles for routine laboratory analysis. Later a recording system may be developed.

X. CONCLUSIONS

36. Conclusions--The intermittent pumping sampler collects a 28 gallon sample every 30 minutes. The sample is pumped into a sedimentation tank and the suspended sediment is weighed as it deposits on a weighing pan near the bottom of the sedimentation tank.

The intermittent pumping sampler maintained a 76 percent operational record during the first full season of operation in 1958, but because of frequent failures due to low river discharge, the operational record dropped to 42 percent for the 1959 season. Most of the operational failures were caused by fish in the intake or by sediment covering the intake opening. A fish trap has prevented fish from harming the pumping system but the present intake structure will not provide continuous sampling in a shallow shifting river without frequent maintanence.

The present intermittent pumping sampler will collect a representative sample from a low velocity stream with suspended sediment consisting of fine sand sizes and smaller. Samples pumped from streams of higher velocity and with suspended sediment of coarse sands will contain at least 80 percent of the concentration at the intake. The average cross section concentration of the North Loup River was 19 percent greater than the concentration of the river at the sampler intake.

During periods of very fine suspended-sediment discharge the flushing water removes up to 35 percent of the sample concentration from the sedimentation tank. The average sediment loss of the present intermittent pumping sampler is 23 percent. Addition of a flocculating agent would decrease the sediment loss.

The spring-transformer scale can measure the weight of the deposited sediment to the nearest one pound. The output of the present scale is affected by temperature variations.

In its present state of development the intermittent pumping sampler could be operated with success at carefully selected sites but more developement is needed before it can be recommended for general operation, particulary on small or emphemeral streams.

XI. APPENDIX

37. Description of gaging station--Descriptive data for gaging station on North Loup River near St. Paul, Nebr., as given in Surface Water Supply of the U. S., 1957, Part 6-B: U. S. Geol. Survey Water-Supply Paper 1510.

Location: Lat 41°15'35", long 98°26'50", in sec. 22, T. 15 N., R. 10 W., on right bank 310 ft (revised) downstream from bridge on U. S. Highway 281, 3 miles north of St. Paul, and 4 miles upstream from confluence with Middle Loup River.

Drainage area: 4,460 sq mi, approximately, of which about 1,270 sq mi contribute directly to surface runoff.

Records available: May 1895 to October 1897, April to October 1899, April to December 1903, August 1928 to September 1957.

Gage: Water-stage recorder. Datum of gage is 1,759.39 ft above mean sea level, unadjusted. Prior to Aug. 16, 1928, staff gages at several sites within 1 mile of present site at various datums. Aug. 16, 1928 to Mar. 19, 1934, chain gage and Mar. 20, 1934, to Sept. 8, 1954, water-stage recorder at site 50 ft upstream at datum 3.0 ft higher. Sept. 9-30, 1954, water-stage recorder at present site at datum 3.0 ft higher.

Average discharge: 31 years (1895-97, 1928-57), 888 cfs. (642,900 acre-ft per year).

Extremes: 1895-97, 1899, 1903, 1928-57: Maximum discharge 90,000 cfs (estimated) June 6, 1896; minimum daily, 85 cfs Aug. 8, 1941.

Remarks: Records fair except those for periods of ice effect, which are poor. Discharge measurements generally made once a week. Natural flow affected by diversions and ground-water withdrawals for irrigation and return flow from irrigated areas.

Daily water discharges of the North Loup River for periods of sampler operation are shown in Table 8. The figures shown are from provisional records and are subject to revision.

TABLE 8

DAILY WATER DISCHARGES NORTH LOUP

	1957 (Sept. 2-Nov. 20)			1958 (Apr. 30-Oct. 8)				
Day	Sept.	Oct.	Nov.	Apr.	May	June	July	Aug.
1		859	1,060		1,320	1,130	992	1,030
2	570	882	1,140		1,260	1,020	769	980
3	544	859	1,180		1,180	955	950	882
4	544	848	1,180		1,100	859	1,130	813
5	598	836	1,140		1,030	870	836	769
6	656	848	1,100		968	894	769	666
7	617	1,000	1,090		905	882	813	627
8	588	1,030	1,110		1,020	824	738	646
9	727	980	1,100		1,100	813	3,070	588
10	980	968	1,020		942	918	980	526
11	905	930	968		894	942	1,380	492
12	848	942	992		836	1,140	836	526
13	1,240	942	1,000		848	1,170	790	444
14	2,670	1,020	1,060		1,220	1,030	859	444
15	1,530	2,440	1,070		1,370	1,090	813	444
16	1,130	2,000	1,130		1,240	1,040	716	436
17	1,020	1,100	1,300		1,100	942	685	500
18	918	1,020	1,350		1,040	882	696	444
19	1,040	992	1,220		930	836	3,760	428
20	1,460	1,020	1,170		870	848	1,780	413
21	1,000	1,300			980	848	2,700	406
22	992	1,260			930	918	1,700	420
23	942	1,300			942	930	1,260	500
24	918	1,180			870	930	4,860	553
25	894	1,180			790	894	3,100	544
26	894	1,110			802	824	1,300	526
27	894	992			1,000	780	1,180	460
28	882	980			1,240	748	1,450	428
29	894	1,020			894	738	1,380	468
30	870	1,060		1,450	918	696	1,130	444
31		1,060			968		1,060	436
Total	27,765	33,958	22,380	1,450	31,507	27,391	44,482	17,283

TABLE 8

RIVER FOR PERIODS OF SAMPLER OPERATION

1958		1959 (Apr. 28-Oct. 26)						
Sept.	Oct.	Apr.	May	June	July	Aug.	Sept.	Oct.
452	836		1,000	918	1,130	303	544	955
452	905		968	859	968	340	544	992
468	942		980	836	859	359	526	980
476	930		1,000	824	905	372	553	905
562	905		1,110	780	955	406	562	870
666	894		1,230	780	1,500	400	562	824
727	870		1,170	716	942	400	553	882
706	848		1,140	666	824	366	518	1,070
696			1,260	636	769	359	509	905
656			1,370	617	727	386	535	894
666			1,260	617	675	400	526	918
675			1,260	636	656	400	526	942
675			1,180	696	617	393	544	980
696			1,130	666	553	436	570	1,060
882			1,040	627	500	526	579	1,090
1,280			955	598	460	544	588	1,070
882			955	526	535	492	675	1,060
813			968	870	836	492	780	1,040
769			882	544	824	460	870	992
758			1,090	588	727	444	894	980
727			1,220	607	562	413	905	955
727			1,090	696	500	420	905	955
716			1,100	824	452	460	882	1,030
738			1,020	727	476	509	930	992
716			968	646	413	562	992	992
716			955	636	386	562	1,020	1,030
716			894	656	346	526	1,020	
748		1,130	824	738	334	562	1,070	
769		1,090	859	758	322	588	1,030	
802		1,040	859	1,400	297	526	918	
			1,140		291	535		
21,332	7,130	3,260	32,877	21,688	20,341	13,941	21,630	25,363

38. Description of sediment station--Descriptive data for sedimentation station on North Loup River near St. Paul, Nebr., as given in Quality of Surface Waters of the U. S., 1953, Parts 5-6: U. S. Geol. Survey Water-Supply Paper 1291.

Location: At bridge on U. S. Highway 281, 60 ft upstream from gaging station, 3 miles north of St. Paul, Howard County, and 4 miles upstream from confluence with the Middle Loup River.

Drainage Area: 4,460 sq mi, approximately, of which about 1,270 sq mi contribute directly to surface runoff.

Records Available: Water temperatures: April to November 1948.
Sediment records: April 1946 to June 1953 (discontinued).

Extremes: 1946-53: Sediment concentrations: Maximum daily, 17,200 ppm Apr. 27, 1951; minimum daily, not determined.
Sediment loads: Maximum daily 463,000 tons June 22, 1947; minimum daily, 20 tons Aug. 3, 1946, Feb. 22, 1953.

Periodic suspended-sediment discharge measurements were made on the North Loup River near St. Paul, Nebr., from July 1, 1953 to September 30, 1958. Results of the measurements made during periods of sampler operation are shown in Table 9. Five low water measurements made by project personnel, 2 at a section near the surface water gage in 1958 and 3 at a section near the sampler intake in 1959, are included. The figures shown are from provisional records and are subject to revision.

39. Results of St. Paul intake tests--Tables 10, 11, and 12 show the results of the St. Paul intake tests described in Section 21.

TABLE 9

SEDIMENT DISCHARGE MEASUREMENTS NORTH LOUP RIVER
FOR PERIODS OF SAMPLER OPERATION

Date	Time	Location	Suspended Sediment								
			Concentration (ppm)	Percent finer than indicated size (mm)							
				0.002	0.004	0.016	0.062	0.125	0.250	0.500	1.000
				Pipette analyses			Visual accumulation tube analyses				
1957 (September 2 - November 20)											
Oct. 14	11:40 am	Bridge	343	--	--	--	43	58	73	100	--
Oct. 28	12:35 pm	Bridge	430	--	--	--	26	46	82	98	100
Nov. 12	10:10 am	Bridge	356	--	--	--	25	42	77	99	100
1958 (April 30 - October 8)											
May 12	12:40 pm	Bridge	226	--	--	--	35	53	78	100	--
May 26	10:45 am	Bridge	313	--	--	--	44	56	80	98	100
June 9	11:10 am	Bridge	278	--	--	--	48	63	92	100	--
June 17	5:15 pm	S.W. gage	302	--	--	--	--	--	--	--	--
June 23	12:50 pm	Bridge	291	--	--	--	58	72	92	100	--
July 7	6:10 pm	Bridge	771	45	53	68	89	94	98	100	--
July 9	3:00 pm	Bridge	11,200	42	54	69	93	96	98	100	--

TABLE 9 (continued)

SEDIMENT DISCHARGE MEASUREMENTS NORTH LOUP RIVER
FOR PERIODS OF SAMPLER OPERATION

Date	Time	Location	Suspended Sediment								
			Concentration (ppm)	Percent finer than indicated size (mm)							
				0.002	0.004	0.016	0.062	0.125	0.250	0.500	1.000
				Pipette analyses			Visual accumulation tube analyses				
1958 (continued)											
July 20	9:25 am	Bridge	3,700	27	30	41	88	92	97	100	--
July 21	2:55 pm	Bridge	2,740	11	12	17	71	79	91	100	--
Aug. 4	11:15 am	Bridge	257	--	--	--	77	86	99	100	--
Aug. 18	12:30 pm	Bridge	150	--	--	--	83	90	98	100	--
Aug. 26	1:50 pm	S.W. gage	311	--	--	--	--	--	--	--	--
Sept. 8	12:10 pm	Bridge	350	--	--	--	68	77	94	100	--
1959 (April 28 - October 26)											
June 3	1:15 pm	Samp. Intake	246	--	--	--	--	--	--	--	--
June 24	10:35 am	Samp. Intake	543	--	--	--	--	--	--	--	--
Aug. 22	1:35 pm	Samp. Intake	166	--	--	--	--	--	--	--	--

TABLE 10

RESULTS OF STANDARD INTAKE TESTS

Date of Sampling	Time	River Samples		Splitter Samples		Ratio (1)
		Number	Avg.Conc. (ppm)	Number	Avg.Conc. (ppm)	
4/30/58	9:50 am	6	262	6	284	1.08
	5:30 pm	6	230	3	241	1.05
5/14/58	10:30 am	6	926	3	950	1.03
	11:55 am	6	1,100	3	1,130	1.03
	2:20 pm	6	1,690	3	1,720	1.02
	3:05 pm	6	1,780	3	1,780	1.00
	3:35 pm	6	2,110	3	2,030	0.96
	4:35 pm	6	2,780	3	2,800	1.01
	5:15 pm	6	2,860	3	2,890	1.01
	6:00 pm	6	3,020	3	2,990	0.99
	6:30 pm	6	3,220	3	3,200	0.99
6/3/58	12:55 pm	6	181	6	188	1.04
6/4/58	3:00 pm	3	164	3	163	0.99
	3:30 pm	3	180	3	179	0.99
	4:00 pm	3	172	3	165	0.96
6/17/58	10:30 am	3	223	3	224	1.00
6/18/58	12:00 m	3	197	3	200	1.02
	12:30 pm	3	199	3	205	1.03
	4:30 pm	3	207	3	225	1.09
7/9/58	9:30 am	3	20,900	3	20,500	0.98
	6:00 pm	3	9,220	3	9,180	1.00
7/10/58	8:00 am	3	3,730	3	3,720	1.00
	9:00 am	3	3,420	3	3,360	0.98
8/26/58	10:00 am	3	250	3	251	1.00

TABLE 10 (continued)

RESULTS OF STANDARD INTAKE TESTS

Date of Sampling	Time	River Samples		Splitter Samples		Ratio (1)
		Number	Avg.Conc. (ppm)	Number	Avg.Conc. (ppm)	
8/26/58	10:30 am	3	247	3	243	0.98
	3:30 pm	3	256	3	249	0.97
9/17/58	12:30 pm	3	393	3	370	0.94
	2:30 pm	3	357	3	359	1.01
6/3/59	2:10 pm	2	204	2	226	1.11
6/7/59	1:10 pm	2	178	2	172	0.97
6/23/59	2:40 pm	2	1,180	2	1,130	0.96
6/24/59	11:10 am	2	418	2	426	1.02
10/8/59	9:15 am	2	1,340	2	1,300	0.97
	4:45 pm	2	808	2	778	0.96

(1) Concentration of splitter sample/concentration of river sample

TABLE 11

RESULTS OF ELBOW INTAKE TESTS

Date of Sampling	Time	River Samples Number	River Samples Avg.Conc. (ppm)	Splitter Samples Number	Splitter Samples Avg.Conc. (ppm)	Ratio (1)
Pointed up.						
6/3/58	2:50 pm	6	174	6	164	0.94
6/4/58	1:00 pm	3	196	3	186	0.95
	1:30 pm	3	156	3	162	1.04
	2:00 pm	3	173	3	167	0.96
6/17/58	11:50 am	3	248	3	248	1.00
	12:00 m	3	236	3	248	1.05
	12:30 pm	3	240	3	246	1.02
Pointed up stream						
6/3/58	1:00 pm	6	181	6	188	1.04
6/4/58	10:30 am	3	191	3	181	0.95
	11:00 am	3	180	3	190	1.06
	11:30 am	3	173	3	167	0.96
6/17/58	1:30 pm	3	238	3	243	1.02
	2:00 pm	3	243	3	254	1.04
	2:30 pm	3	225	3	237	1.05
Pointed Down						
6/3/58	3:30 pm	6	156	6	154	0.99
6/4/58	8:30 am	3	170	3	161	0.95
	9:00 am	3	186	3	177	0.95
	9:30 am	3	165	3	179	1.08
6/17/58	10:50 am	3	228	3	232	1.02
	11:00 am	3	241	3	265	1.10
	11:30 am	3	264	3	257	0.97

(1) Concentration of splitter sample/concentration of river sample.

TABLE 12

RESULTS OF NIPPLE INTAKE TESTS

Date of Sampling	Time	River Samples		Splitter Samples		Ratio (1)
		Number	Avg. Conc. (ppm)	Number	Avg. Conc. (ppm)	
Short Nipple						
6/18/58	1:15 pm	3	198	3	210	1.06
	1:30 pm	3	213	3	211	0.99
	2:00 pm	3	199	3	207	1.04
Long Nipple						
6/17/58	3:00 pm	3	236	3	240	1.02
	3:30 pm	3	231	3	256	1.11
	4:00 pm	3	246	3	251	1.02
6/18/58	3:00 pm	3	205	3	214	1.04
	3:30 pm	3	209	3	215	1.03
Long Nipple with Plate						
6/17/58	4:30 pm	3	219	3	231	1.05
	5:00 pm	3	223	3	222	1.00
	5:30 pm	3	223	3	219	0.98

(1) Concentration of splitter sample/concentration of river sample